THE REVISED EUROPEAN BATHING WATER DIRECTIVE: A CASE FOR INTERDISCIPLINARITY?

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I certify that this thesis is the true and accurate version of the thesis approved by the examiners.

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ABSTRACT

The Revised Bathing Water Directive will have a major impact on the way that Competent Authorities assess water quality. It requires work in various disciplines to be streamlined into delivering the methods and approaches needed to deliver the requirements of the Directive. To achieve this, Competent Authorities will have to engage effectively with all stakeholders and embrace the principles of Integrated Coastal Zone Management. This does not currently happen

This research assessed the legislative and managerial development of the revised Bathing Water Directive proposal COM 581 and developed methods and approaches to support this, through the production of an interdisciplinary Bathing Water Management Framework (BWMF). This led to the creation of biological monitoring and communication methods that could deliver the requirements of the revised Directive.

This research showed that the revised Bathing Water Directive will require Competent Authorities to work with others and look at novel ways of gathering and communicating information required for the Directive; including biomonitoring and emerging communication technologies. This will require the UK and Europe as a whole to embrace the principles of Integrated Coastal Zone Management (ICZM). This research has shown that interdisciplinary research can be successful in answering complex, cross-cutting issues such as how to develop a holistic overview of Bathing Waters. When compared to a monodisciplinary approach, this research has advanced in several disciplines and also created a brand new intellectual space in the form of the framework. Whilst the interdisciplinary outputs are powerful the research has also delivered the article requirements of the Directive.

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TABLE OF ABBREVIATIONS

ABM	Active Bio Monitoring
AChE	Acetylcholinesterase
AHD	American Heritage Dictionary
BOD	Biochemical Oxygen Demand
BWD	Bathing Water Directive
BWMF	Bathing Water Management Framework
BWP	Bathing Water Profile
BSE	Bovine Spongiform Encephalitis
CAP	Common Agricultural Policy
CbEs	Carboxylesterases
CEA	Cellular Energy Allocation
CFU	Colony Forming Unit
CLL	Cornell Law Library
COM 581	COM 581/2002/0254 The proposed Bathing Water Directive
COR	Committee of Regions
CSL/EP	Council and European Parliament Conciliation Committee
CSO	Combined Sewer Overflow
CSS	Cascading Style Sheets
CUP	Cambridge University Press
DEFRA	Department for Environment, Food and Rural Affairs
DG	Directorate General

DMSO	Dimethyl Sulphoxide
DNA	Dioxyribose Nucleic Acid
DNBT	5, 5-dithiobis-2-dinitrobenzoate
EAP	Environmental Action Programme
EC50	Effective Concentration
EC	European Community
ECJ	European Courts of Justice
ECSC	European Coal and Steel Community
EEA	European Environment Agency
EEB	European Environmental Bureau
EEC	European Economic Community
EIP	Environmental Improvement Plan
ELV	Emission Limit Value
EMU	European Monetary Union
EP	European Parliament
EPC	Committee on the Environment, Public Health and Consumer policy
ERDF	European Regional Development Fund
ESC	European Economic and Social Committee
ETS	Electron Transport activity
EU	European Union
EURATOM	European Atomic Energy Community
FC	Faecal Coliforms

GM	Genetic Modification
GSTs	Glutathione Transferases
HLS	Harvard Law School
HMSO	Her Majesty's Stationary Office
HOL	House of Lords
HPLC	High Pressure Liquid Chromatography
HTML	Hyper Text Markup Language
ICZM	Integrated Coastal Zone Management
IP	Internet Protocol
IPPC	Integrated Pollution Prevention and Control
LAIM	The committee on Legal Affairs and the Internal Market
LC	Lethal Concentration
LD	Lethal Dose
MCA	Multi-Criteria Analysis
MDA	Malonedialdehyde
MN	MicroNucleus formation
MP	Member of Parliament
MPSS	Molluscan Physiological Saline Solution
MS	Mass Spectrometry
MXR	Multixenobiotic Resistance
NGO	Non Governmental Organisation
NOEC	No Observable Effects Concentration

NRR	Neutral Red Retention
PBM	Passive BioMonitoring
PPM	Parts Per Million
RII	Relative Importance Index
RNA	Ribose Nucleic Acid
RTT	the committee of Regional Policy, Transport and Tourism
SE	Scottish Executive
SEPA	Scottish Environment Protection Agency
SFG	Scope For Growth
SMBRC – TAG	Santa Monica Bay Restoration Commission – Technical Advisory Group
SNH	Scottish Natural Heritage
SNIFFER	Scotland and Northern Ireland Forum for Environmental Research
TEF	Tay Estuary Forum
TOSC	Total Oxidant Scavenging Capacity
UK	United Kingdom
UN	United Nations
UN ECE	United Nations Economic Commission for Europe
UNEP	United Nations Environmental Body
URL	Uniform Resource Locator
US	United States
W3C	World Wide Web Consortium

WET	Whole Effluent Toxicity
WFD	Water Framework Directive
WHO	World Health Organisation
WYSIWYG	What You See Is What You Get

CHAPTER ONE - INTRODUCTION

1.0 BACKGROUND

On 24th October 2002, the European Commission adopted a proposal for a revised Directive of the European Parliament and of the Council concerning the Quality of Bathing Water COM (2002) 581 (EC, 2002).

Bathing waters of which there are 60 in Scotland are defined as;

'Those fresh or seawaters in which bathing is either explicitly authorised.... or is not prohibited and is traditionally practised by large numbers of bathers' (EC, 1976)

The original Bathing Water Directive 1976/160 was created to protect citizens' health and protect the environment by reducing pollution in bathing waters and preventing further deterioration in those waters. This is a quality Directive, whereby there is a dual list described as imperative (I) and guide (G). These are water standards that Member States must obtain, i.e. Member States' water quality should not fall below I standards and should aim for G standards. Bathing Waters classified under the Directive are based on a consideration of 19 indicators including microbiological standards, pH values and physico-chemicals parameters, in a purely scientific grading of bathing waters.

This approach was standard on many directives released in the 1970s and reflected the state of knowledge and experience of the early 1970s, both technically and socially. Since 1976, epidemiological knowledge has progressed and communication and administrative management systems also. The revised Directive strongly changes the ethos of Bathing Water with the need for wide-ranging management plans incorporating social, economic and environmental factors rather than just technical compliance as before.

In 2000, the Water Framework Directive 2000/60 (WFD) (EC, 2000) was launched with an aim to establish 'good ecological status' across European waters. Previously each competent authority within each country created its own systems derived from European Directives. The WFD requires the development of Catchment Management Plans and in the case of trans-boundary waters such as the Rhine and the Danube rivers, integrated systems need to be developed between the affected countries. In the WFD, designated waters that are to be protected include coastal waters and, from this, the revised Bathing

Water Directive (BWD) has been aimed at the creation of an effective management system that can be applied to bathing waters Europe-wide.

The new proposal represents a significant tightening of the health standards relating to faecal pollution. Whilst making use of only two bacteriological indicator parameters, the revised Directive requires for the first time long-term quality assessment and management methods to reduce both monitoring frequency and monitoring costs. Well-developed management of bathing waters and extensive information given to the public replaces the present monitoring and retrospective compliance approach. The revised Directive foresees a need for assessment of each bathing site, definition of and the likely sources of contamination, and the production of a management plan to minimise the risks to bathers.

These management techniques include the establishment of Bathing Water Profiles (BWPs) which instead of only using bio-chemical monitoring methods as indicators of bathing water status, include five additional factors to define risk of pollution to a bathing water, as highlighted below:

- the physical, geographical and hydrological characteristics of the water;
- a qualitative and quantitative identification of all sources of pollution;
- an assessment of their potential to pollute bathing water – including all accidental and risk potential to human health expressed in nature, volume and effects in terms of distance from the bathing water;
- a description of monitoring points ;
- an assessment of the extent to which this monitoring provides representative information for all bathing water users.

The revised Directive requires that information on the status of a bathing site, the monitoring data on water quality, the management plan and other relevant information is readily available to the general public. As well as being physically displayed at the site, information should also be available through the media, such as the Internet. The users of bathing water sites should be actively involved in the development of the management plan by way of public consultations. The biggest challenges for competent and local authorities will be the designation and delivery of the many new tasks, who actually has to carry out

the extra work and responsibilities which include the creation of monitoring calendars and developing Bathing Water Profiles amongst the other management requirements.

To summarise, under the revised BWD Bathing Waters shall be actively managed and risks assessed, rather than using a retrospective compliance approach as in the original Directive 76/160. This presents various issues for competent authorities over a wide range of traditional disciplines including management, communication, information, biology and chemistry. To address this, interdisciplinary research needs to be carried out to assess the revised Directive and to develop methods and approaches that will satisfy the requirements of the revised Directive, for competent authorities.

The wide scope of the Directive raises a need to question how best to approach the research. Each component may itself be a relevant research package, however, in line with holistic thinking as in the WFD (EC, 2000), it is important to have an appreciation of how the components may interact and integrate in the real world. Further to this when implementing the revised Directive, the competent authorities will not be able to pick and choose the aspects of the Directive that they want to develop and run. Consequently, the research needs to embrace a range of disciplines instead of focusing on one.

Engaging in research using more than one discipline requires a good understanding of how these disciplines may interact. Table 1 from Acutt et al. (2000) shows how collaboration between disciplines increases from mono-disciplinary to transdisciplinary.

Table 1 -Table showing collaboration between disciplines intensifies towards a goal of transdisciplinarity

Disciplinary	A domain of scientific or social science enquiry with its own community of experts, with distinct practice, concepts, skills, peer review and methods of enquiry.
Crossdisciplinary	The transposition of rules, concepts and methods from one discipline for a specific purpose in another / different discipline.
Multidisciplinary OR Pluridisciplinary	Bringing together of different disciplines to work on a common problem/objective but without integration of the different disciplinary perspectives/contributions.
Interdisciplinary	An eclectic approach integrating different disciplines for solving complex problems, encompassing methodologies, methods and worldviews. It involves an interactive, communicative, information based and holistic way of thinking. It is fluid and adaptable to the problem that has to be solved.
Transdisciplinary	Achievement of a common set of rules, methods (axiomatics) and the integration and co-operation of all levels of knowledge towards a common goal.

From Table 1 it can be seen that this research on the Directive and its implementation requires an interdisciplinary approach. Lattuca (2001) further defines interdisciplinarity research variables as shown in Table 2.

Table 2- Lattuca's definitions of interdisciplinary scholarship

Type of research	**Definition**
Informed disciplinarity	Disciplinary questions requiring outreach to other discipline(s)
Synthetic interdisciplinarity	Questions that link disciplines
Transdisciplinarity	Questions that cross disciplines
Conceptual interdisciplinarity	Questions without a compelling disciplinary basis

Table 2 shows that the research question does not have a compelling disciplinary basis and is conceptual interdisciplinarity. It could be argued that the requirements are from European law. The ethos of the European environment and its management has changed so much in the last 30 years that without a grasp of how to develop approaches and methods from the law, no progress would ever be made. There needs to be a symbiotic approach between all disciplines to fully realise an end product. This means that the work needs to understand conceptual interdisciplinarity.

Employing interdisciplinary research methods brings several advantages and disadvantages that need to be addressed explicitly early on in the thought process. Knowing these issues helps both reader and researcher to understand what the results of the research truly show. Acutt (2000) states, in interdisciplinary research there is an 'inherent trade-off between the depth of disciplinary and the breadth of interdisciplinary knowledge'.

The advantage of this type of research is the ability to address complex issues that monodisciplinary research could not, such as how best to implement a revised Bathing Water Directive in its entirety (Nissani, 1997). If each disciplinary requirement in COM 581 was addressed in isolation then continuity would quickly be lost. This is typically true of all European environmental law and policy and is why the various environment agencies exist.

The disadvantage of this holistic approach is that there could be loss of deeper understanding of each discipline studied within the research. This could then lead to loss of rigour and robustness that is the foundation of many disciplines. This needs to be monitored throughout the whole research. If and how successful the use of interdisciplinary research is will be crucial in the outcomes of the research overall.

1.2 AIM

The overall aim of this research is to assess the legislative and managerial development of the Bathing Water Directive proposal COM 581 and to develop methods and approaches to support this, through the production of a Bathing Water Management Framework (BWMF).

1.3 OBJECTIVES

1. Review and develop understanding of new legislation and management practices associated with COM 581 and the effects on competent authorities and local authorities;

2. Review current knowledge of lower order organismal biomarkers and associated methodologies, to identify the most suitable to use in support of COM 581 and verify the effectiveness of the biomarker systems using methodologies identified;

3. Review current communication technologies, and research to develop the most appropriate technology that would be capable of effectively disseminating information to the public;

4. Address the issues that have arisen from the legislation review, and determine appropriate bathing water management practices;

5. Create the BWMF, testing the system with controlled societal groups, before release into the public domain for 'live' testing, during a bathing water season.

1.4 OVERVIEW OF METHODOLOGY

The research was carried out using an interdisciplinary approach, involving three disciplines, namely Law, Biological Science and Communication Technology. Section 2.1 contains methods for the review of the Directive and associated materials; Section 3.3 addresses multi-criteria analysis of biological methods, Section 3.4 and 3.5 detail biological monitoring methods. Section 4.5 contains details of methods carried out for communication approaches.

The methodologies are in various areas of the thesis, which could be seen as fragmented, however each methodology forms a part of the overall homologue, the BWMF. A

framework has been used in interdisciplinary research extensively due to the need to deliver a practical system from a conceptual interdisciplinary question such as in this research (Lattuca, 2001). Figure 1 shows how the work 'fits' together in driving the creation of the framework.

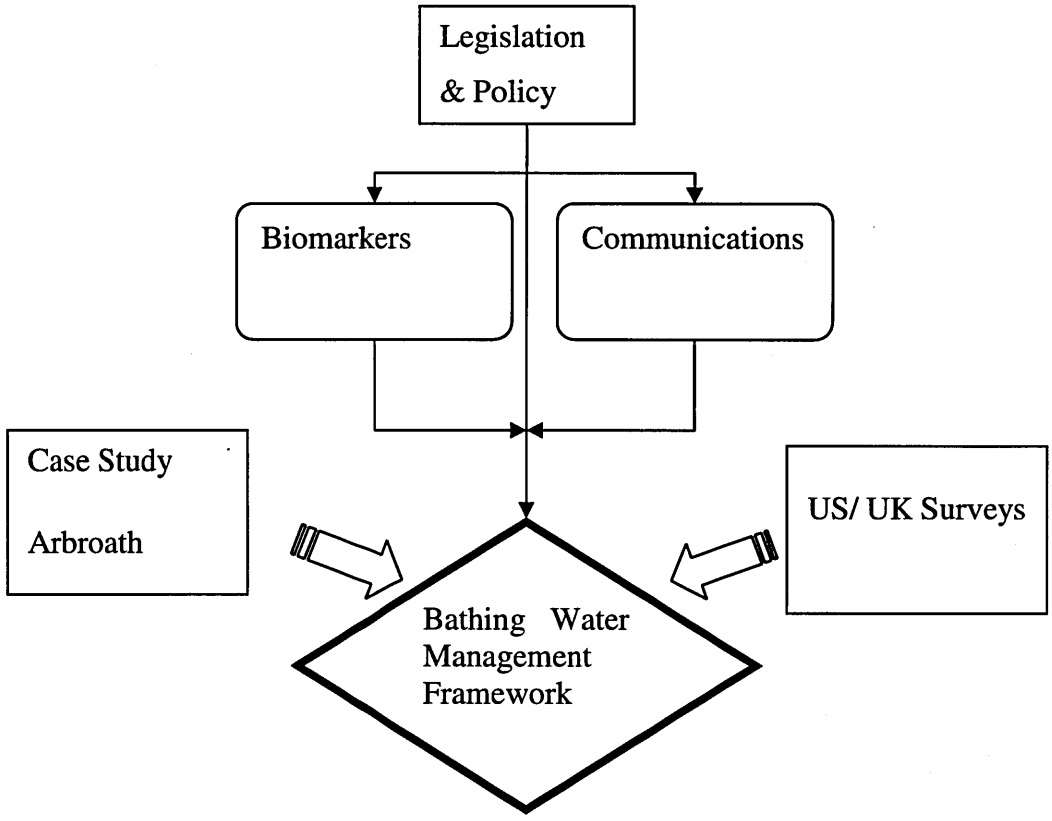

Figure 1 - How the various disciplines integrate to produce the BWMF

When looking at other research that has used frameworks to deliver interdisciplinary research, it can be seen that they are used in similar ways; for example Hackney (2006) uses a framework to 'tie together' (p.10) nine factors used for evaluating web services, Herrick et al. (2006) use a framework 'for organising, synthesising, and applying the evolving understanding of arid land ecosystems' (p.3). Mussachio et al. (2005) actually use a framework to discuss interdisciplinarity versus disciplinarity in ecological change research. These examples help to show that a framework is a useful method of integrating various disciplines to a common goal.

1.5 STRUCTURE OF THE THESIS

Chapter One

This chapter is the introduction and contains the background to the research, aims and objectives, how the work was carried out and a summary of key findings of the thesis.

Chapter Two

This chapter presents findings of the review of the legal background to the revised Directive including the development of European environmental law as a whole and tracks and assesses the key points of revising the Directive. This chapter demonstrates how the Directive has formed since its inception and helps to establish what components are critical to the BWMF.

Chapter Three

This chapter addresses the biomonitoring needed for the revised Directive and comprises a literature review of appropriate methods, an explanation of how the final methods were selected and the testing of the methods, with results and conclusions of their usefulness within a regulatory framework, namely the BWMF.

Chapter Four

In Chapter Four, work is carried out to consider how best to meet the informational needs established in the revised Directive and how to best deploy this to the public and other stakeholders. This contains a review of mass communication and how best to relate this to risk communication, which is a central tenet of this research.

Chapter Five

This chapter is the crux the research and brings together all the information gathered in Chapters Two to Four and focuses on two main aspects of the research; the theoretical understanding of the BWMF and the subsequent practical delivery and testing of the BWMF in a bathing water season. This chapter, building on the other work within the thesis, helps to deliver the overall aim as detailed in 1.2.

Chapter Six

This chapter contains conclusions, discussions and suggestions for future work in this area of research.

Chapter Seven

Chapter Seven contains the references for the research.

1.6 SUMMARY OF KEY FINDINGS

This research shows that the revised Bathing Water Directive will require Competent Authorities to develop new practices in response to the move towards management of water bodies that has been progressing since the Water Framework Directive. This will require them to work with others and look at novel ways of gathering and communicating information required for the Directive; including biomonitoring and emerging communication technologies. This will require the UK and Europe as a whole to embrace the principles of Integrated Coastal Zone Management (ICZM).

Using interdisciplinary research this study has created a Bathing Water Management Framework (BWMF) which has helped to fulfil the requirements of the revised Directive. This has shown that interdisciplinary research can be successful in answering complex, cross-cutting issues such as how to develop a holistic overview of Bathing Waters. When compared to a monodisciplinary approach this research has advanced in several disciplines and also created a brand new intellectual space in the form of the framework. Whilst the interdisciplinary outputs are powerful the research has also delivered the article requirements of the Directive.

The major drawback to the research was the lack of time to develop specific areas, with overarching efforts placed towards generating the homologue. The work as such could have benefited from data being collected over several seasons.

CHAPTER TWO - REVIEW OF EUROPEAN WATER LAW AND THE DEVELOPMENT OF COM 581 THE NEW BATHING WATER DIRECTIVE

2.0 PURPOSE OF THE CHAPTER

Chapter 1 showed that the research uses conceptual interdisciplinarity and requires the use of various disciplines, namely Law, Biological Sciences and Communication Sciences. Without a clear understanding of the legal requirements of the Directive and the related context, both the biological science and communication technologies created could be ineffective.

As stated in chapter 1, a key issue with interdisciplinary research is the inherent trade off between breadth and depth of knowledge. A full review of the law and how it was established was required. This informed the research of how different options developed within the management system could work and how they have been progressed previously. Further to the need for an interdisciplinarian to gain a firm grasp on all disciplines studied; there is a practical purpose for a full review. COM 581 lists the requirements of the Directive; it does not explain what the options are, how to progress them or even what is recommended. For this an intrinsic understanding of European environmental law is necessary. This law review then fed directly into the development of the framework.

In all European laws the principle of subsidiarity exists, whereby 'In areas which do not fall within its [the European Commission's] exclusive competence, the Community shall take action, in accordance with the principle of subsidiarity' (EC, 1993). Subsidiarity states that matters should be handled by the smallest or lowest competent authority. This means that in each Member State, there can be different monitoring regimes and methods used. Nevertheless these still need to conform to the parameters laid out in the particular directive or regulation. This confirms the need for interdisciplinary research within European environmental law due to the cross-cutting nature of the work.

In an effort to fully understand the legal requirements of COM 581, this chapter looks at both the evolution of European environmental law and COM 581 specific developments.

Section 2.1 discusses the sources used for the chapter.

2.1 LEGAL RESEARCH METHODS

Due to the interdisciplinary nature of the research it was crucial to make sure that there is a high-quality depth of knowledge of not only COM581 but also associated European legislation and policy, historical development of policy, international treaties and agreements and also stakeholder opinions of COM581. Without full understanding of this knowledge, subsequent research into the practical applications of COM581 would be severely degraded. This insight gives the researcher and reader a great understanding of the pressures and drivers that exists within the development of European law.

2.1.1 Legal Research Guidelines

Legal research like other subject reviews needs to have clear objectives at an early stage. The Cornell University Law Library (CLL) has produced a set of key statements (CLL, 2005) that must be considered before a legal review begins. The ones relevant to this research are shown below:

- be clear of the scope of the research, how detailed the study should be;
- articulate the issue to understand the informational needs and thus sources;
- consider which legal systems and entities may be affected such as English Law, European Community Law and Scots Law etc.

Further to these questions, both the CLL and Holborn (2001) state the following issues in legal research:

- choose search Keywords carefully particularly with electronic sources which can generate over-retrieval whereby the researcher has to filter many more documents;
- no single source is comprehensive;
- people are often better than books – people within the organisation and further afield may be an expert in the field of research addressed and so may have the information to hand;
- understand the value or currency of the information – in law using the most up to date information is often critical;
- use secondary sources to learn about the legislation being researched, this will give a better fundamental understanding;
- lateral thinking is crucial in any research.

Holborn (2001) summarises the process of legal research using the following steps:

- identify the required legislation (COM581);
- choose the terminology – keywords, terms, synonyms, antonyms;
- choose a starting point – textbooks, directives etc;
- trace information back from directive publication date;
- follow legislation up to present time;
- double-check using alternative sources;
- start again from a different viewpoint.

With these guidelines in place, the next issue was to address the available types and sources of information with regard to COM581 and the wider remit of environmental policy both within the EU and beyond.

2.1.2 Information Sources by Type

In all research there are two categories of information sources available to the researcher, primary and secondary. In legal research primary sources are the legislation the research is concerned with, while secondary sources are the textbooks and other such documents that provide analysis and comment on the legislation (Harvard Law School, 2004).

Within these two categories there is an array of sources, which vary depending on which country's legal system is being used. Figure 2 by Clinch (1995) shows the structure of this information for European law, which COM 581 is part of. Information was also collected from within the UK jurisdiction and other jurisdictions where relevant.

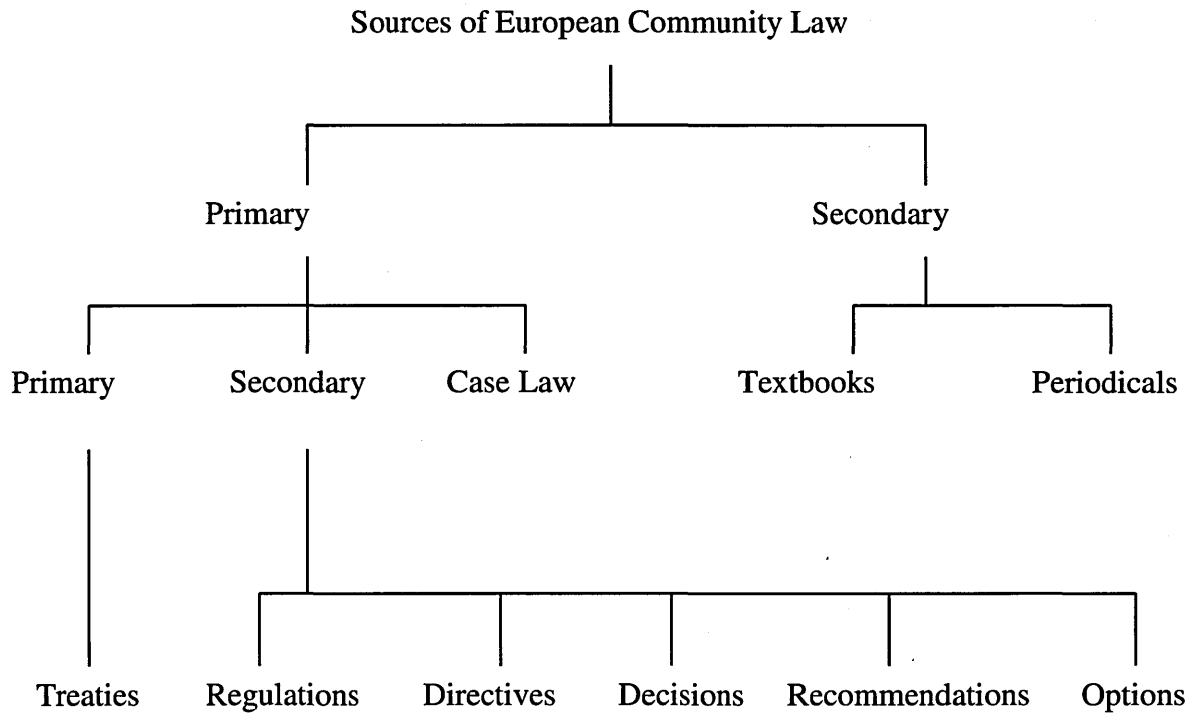

Figure 2 - Outline of European Community law primary and secondary sources

To access this information there are several pathways that can be followed such as printed text and electronic sources. Even though electronic sources have become the prominent information tool within many disciplines including law, printed sources are still valuable. A problem with printed sources is how current they are as the law is ever changing.

With electronic sources and the prevalence of the Internet, accessing a wide range of information is now relatively straightforward; however with this come greater issues such as over-retrieval as highlighted in 2.1.1. Information on the Internet can be found quickly through various portals and in this research, information was found principally at the following locations as detailed in Table 3.

Table 3 - Locations of relevant information on the Internet

Portal Name	**Primary/Secondary Source?**	**Description (as provided by portal)**
Eur-LEX	Primary	'Is the single entry point to the complete collections of EU legal texts in all the official languages'
Her Majesty's Stationary Office (HMSO)	Primary/Secondary	'United Kingdom legal texts and related reports'
European Parliament: Legislative Observatory	Primary/Secondary	'The Legislative Observatory analyses and monitors the interinstitutional decision-making process in the European Union'
Bulletin of the European Union	Secondary	'The Bulletin of the European Union provides a monthly insight into the activities of the European Commission and of the other Community institutions'

Further to these portals, information was also gathered from a wide array of stakeholder websites such as the Scottish Executive, Department for the Environment Food and Rural Affairs (DEFRA), Scottish Environment Protection Agency (SEPA), European Environment Agency (EEA), World Health Organisation (WHO) and the United Nations (UN). The review of the law begins in the next section.

2.2 HISTORY OF THE EUROPEAN UNION

Europe has been the scene of numerous wars; in the period 1870 to 1945 alone, France and Germany fought each other three times, and this included both World War I and II. A number of European leaders became convinced that the only way to secure an enduring harmony between their countries was to unite them both economically and politically (EU, 2003). On the 9th May 1950 Robert Schuman the French Foreign Minister (1948-52) proposed the pooling of the coal and steel industries of Western Europe. The Treaty of Paris was signed by six countries (Belgium, Luxembourg, France, Italy, the Netherlands, and West Germany) on 19th March 1951 (Dedman, 1996) so forming the European Coal and Steel Community (ECSC).

The coal and steel industries were chosen for this process due to the importance of these industries to the economic and military power of the countries involved (El-Agraa, 1998: Dedman, 1996).

The ECSC was such a success that, within a few years, the same six countries decided to go further and merge other sectors of their economies, when on 25th March 1957 they signed the Treaties of Rome, creating the European Atomic Energy Community (EURATOM) and the European Economic Community (EEC) (Sunkins, 2002).

The Euratom Treaty (EEC, 1957) was intended as new impetus for European collaboration and was set up to advance nuclear energy. In fact the idea for Euratom came from the United States (US), which liked the idea of a large, unified European nuclear market (Stirk and Weigall, 1992). The US was the main exporter of nuclear knowledge, nuclear installations and nuclear materials. The US idea for a European nuclear union was taken over and became part of the 1956 Spaak report for the creation of a common European economic market and a separate nuclear common market: the Treaties of Rome. One of the key reasons for a separate treaty for nuclear energy was that the French wished to develop nuclear weapons and nuclear energy independent of the US and the UK. In June 1956, the French Parliament made the option to develop nuclear weapons a prerequisite for its support for Euratom (El-Agraa, 2001).

In 1955, at Messina in Italy, when the foreign ministers of the six countries proposed Euratom, they also proposed a common customs market within Europe to develop

economic productivity and allow Europe to work on equal terms with the superpowers and to revitalise its position in world influence (Stirk and Weigall, 1992).

The EEC began on the 1st January 1958 and established a common market, with an integrated Common Agricultural Policy (CAP); this was the third founding Directive of the eventual European Union, along with the ECSC and Euratom (EC and Tsoukalis, 1983). The EEC was developed with a framework of three major institutions to aid integrity and to ensure policy was correctly regulated. This was particularly important at its inception, when Member States were still cautious of federalism and supranationalism (Stirk and Weigall, 1992). The three institutions were the European Commission, the Council of Ministers and the European Parliament.

The Commission is a politically independent institution that represents and upholds the interests of Europe as a whole and proposes legislation, policies and programmes of action. It is accountable for implementing the decisions of Parliament and the Council (EEC, 1957). The Council of Ministers is the main decision-making body in Europe, and is attended by one member from each state. This member changes depending on the topic of the meeting, such as if CAP was being discussed, then ministers for agriculture would be present.

The Council of Ministers along with the Parliament has responsibility in passing policy and law that has been proposed by the European Commission. Once the law has been passed, it is the responsibility of the European Commission to enforce it, with cases brought to the European Court of Justice (ECJ).

The third major institution in the EEC is the European Parliament and is the voice of the citizens of Europe. The Parliament is seated in political parties rather than Member States, and is voted for every 5 years (EC, 1997). The Parliament's main role in Europe is as with Council, passing law and policy, control of the European budget, and, separate of the Council, it has the responsibility of democratic supervision whereby it has the power to approve or reject the nomination of Commissioners. The Parliament also has the right of censure over the Commission. Figure 3 shows how the three institutions work together in delivering European legislation.

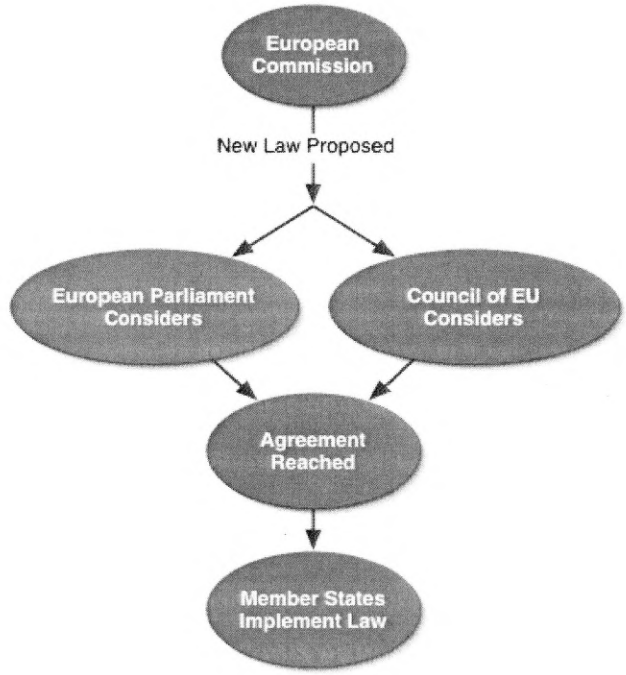

Figure 3 - Mechanism of European Legislation formulation

The EEC was initially a weak officialdom as many countries retained national policy on many issues, but it was seen as a useful blueprint of how European policy could develop. As the ECSC, Euratom and the EEC proceeded, the EEC became much more significant, due to the broad sectors that it covered. The ECSC and Euratom cover complex, narrow areas of economic policy. In 1965 the ECSC and Euratom were absorbed into the EEC, and were seen as a way of developing active integration between Member States (EEC, 1967). From this time the EEC became more relevant to the Member States involved and other states such as Great Britain wanted to join.

Throughout this time in the EEC, development of environmental policies was not considered. The primary reason was the issue of legitimacy. Was there a legal base for it within the remit of a common trade market? Throughout the next section, this and further issues relating to the expansion of the European Community's environmental policy will be discussed This addresses how Europe became a world leader in environmental protection through its policy and legislation.

2.3 EUROPEAN ENVIRONMENTAL POLICY - THE BEGINNING

When the Treaty of Rome was formulated there was no reference to environmental issues. This was a worldwide state of affairs and it was not until the early 1960s that widespread public concern over environmental degradation came to the fore, leading countries to address the issues that may be affecting their citizens. Before this time, environmental threats were dealt with case by case, for example the density of smog in London 1952-3 becoming thicker than normal and so leading to increased mortality in the old and infirm. This led to the introduction of legislation controlling domestic coal fires (Bell and Davis, 2001).

In 1962, Rachel Carson published her book 'Silent Spring' (Carson, 1962) in which she described the persistence of pesticides in the environment and the massive effect on the fauna and flora affected. The book went to number one in the US bestseller list for 31 weeks and sold 500,000 copies in hardback, and was subsequently published in 15 other countries (Newsweek, 1964). Once the modern non-scientific connotation of 'the environment' entered the accepted lexicon, the public concern associated with the subject rose swiftly. Time Magazine stated that it was the issue of the year in 1970 (Brenton, 1994).

In the EEC the main problem with developing environmental policy was that in the original Treaty there was no direct article relating to the enforcement of environmental issues. The EEC was devised as a trade initiative and there was no discussion directed towards the environment. Member States in favour of the environment argued that Article 2 in the Treaty of Rome aims to 'promote ... a harmonious development of economic activities, a continuous and balanced expansion, an increase in stability and accelerated standard of living and closer relations between the States belonging to it' (EEC, 1957) and was a valid reason for protecting the environment within the economic community (Sunkins, 2002).

In 1967 the classification, packaging and labelling of Dangerous Substances Directive (EC, 1967) was to become the first quasi-environmental Directive under the newly formed European Community. This was justified by addressing how diverse classification systems can encumber trade within the common market. The Directive called for all packaging to be adequately secured, so as not to allow release of the substance enclosed and sufficient

signage to draw attention to the effects that the dangerous substance will have. This was the first Directive to take into account the environmental risk that trade items may have. This Directive was established using Article 100 (formerly 94) of the Treaty of Rome, which enables directives to be made that harmonise law and administrative practices that directly affect the functioning of the common market. This article shows a close link between economic and environmental policy (EEC, 2002a).

Other trade directives including the Directive on Noise from Motor Vehicles 70/157 were established to guarantee the flow of trade by committing Member States to permit the importation of vehicles that may not comply with their own particular noise standards (EC, 1970). This also had the effect of reducing noise emissions from motor vehicles and so improving the environment.

In 1972, the United Nations (UN) held a pioneering conference in Stockholm that addressed the relation that man has with his environment and set out to devise:

'A common outlook and ... common principles to inspire and guide the peoples of the world in the preservation and enhancement of the human environment' (UN, 1972).

Stockholm was the first high-level meeting that aimed to involve developing countries and to help them become involved in the environment. Before this it was mostly a preserve of western societies, which, with highly developed infrastructure and funding, could afford it. Developing countries argued that increased pollution was created by increased industrialisation, such as was present in developed countries, and that developing countries' main problems lay in poverty, famine and disease (UN, 1972).

From the conference, a Declaration of the United Nations Conference on the Human Environment (The Stockholm Declaration) was published. The UN also established the United Nations Environmental Body (UNEP) with significant funding and created an action plan for the human environment which had 109 environmental recommendations which included the following:

- a Framework of Environmental Action consisting of environmental assessments and supporting structures such as education and technical cooperation;
- provision of technical and financial assistance to countries wanting to develop Educational, Informational, Social and Cultural Aspects of Environmental Issues;
- recommendations for action at the international level on the identification and control of pollution of broad International Significance, with specific action on:
    - pollution generally;
    - marine pollution.

Stockholm was intended to be a response to global environmental concerns. When the UN carried out a review of actions from Stockholm after 10 years, they found that the actions had only been partly implemented and that the progress of the action plan was not satisfactory (UN, 1982). The benefits of Stockholm were that the environment was discussed at an international level with developing and developed countries. This highlighted the many facets of how the environment is interpreted and how the problems should be resolved.

In 1972, the EC was going through big changes and the Paris Summit in October of that year was the start of a major shake-up in European policy and direction, with work reflecting the Stockholm Conference. In the previous months the United Kingdom, Ireland and Denmark had joined the EC (EC, 1972). With increased Member States, the primary issues discussed at Paris were the further integration of policies, economics and the environment. The Paris Summit was the scene for groundbreaking integration measures between Member States. These included a commitment to the European Monetary Union (EMU), the European Regional Development Fund (ERDF) and the creation of the Environmental Action Programmes (EAPs).

In response to Stockholm and the significant lack of environmental foresight in much of the EC's current and past policy, there was a need to create legislative tools that could be used to address the Member States' citizens concerns over the degradation of the environment (McAllister, 1997).

Similar to the UN's Action Plan, early EAPs were not legally enforceable (6th EAP however does contains decision procedure which is legally binding) and are created in the form of resolutions that have been developed by the community in areas which are deemed important and in which action will be taken in a given time period. Even though not a legal instrument, Member States who sign up to an EAP cannot deny that action in the prescribed area needs to be taken (Sunkins, 2002).

The first EAP was published on 20th December 1973 and forged the link between the environment and achieving Article 2 of the Treaty of Rome. The first EAP (1973-76) laid the foundations for preventative action by stating that:

'...the best environmental policy consists in preventing the creation of pollution and nuisances at source, rather than subsequently trying to counteract their effects' (EC, 1973).

Also in 1973 there was the foundation of the Directorate-General (DG) dealing with matters relating to the environment and consumer protection. DGs form part of the European Executive and execute the equivalent function of civil servants in Member States. They are accountable for the instigation of proposals leading to prescribed Commission proposals (El-Agraa, 2001).

With the advent of environmental awareness and sufficient measures in place to achieve the goals required, there was now for the first time a chance to start making a difference to European environmental issues through primary and secondary legislation, including protection for European waters.

2.4 EUROPEAN WATER LAW

2.4.1 The First Wave

With the establishment of the First EAP, water pollution and its remedy had been placed high in European policies and legislation. In 1973 the first Water Pollution Directive was proposed, so starting the first wave of European water legislation.

The Detergents Directive 73/404 was enacted to regulate the problem of foam that was pervasive throughout Europe's water bodies. This was caused by predominantly domestic use of hard detergents, which cannot be degraded by wastewater treatment processes (EC, 1973a). In line with the ethos of the EC, the Directive was introduced to ban the sale of

detergents that fall below a 90% level of degradability; however there are various methods for testing the biodegradability, which ensured Member States' right to free trade across the EC (Lister, 1996).

In 1975 the Quality of Surface Water for Drinking 75/440 Directive was published with its main aims to reduce pollution and prevent further deterioration in water resources. This was deemed necessary due to the increasing abstraction of potable water, as the European population increased (EC, 1975). The Quality of Surface Water for Drinking 75/440 Directive established features that were to become common throughout European water law using two approaches to tackle pollution, (1) the obligation of limits or restrictions of release of certain pollutants into water bodies and (2) the establishment of quality standards for elected bodies of water. These two approaches were seen as efficient mechanisms that enhanced the quality of water bodies and further encouraged the control of pollutants' access to the aquatic environment, from sparse sources that might not be regulated otherwise (Lister, 1996).

From these two approaches common components that are developed from them run throughout water quality directives and can be summarised as:

- the use of a dual list described as imperative (I) and guide (G), which pertains to water standards that Member States must obtain, i.e. Member States' water quality should not fall below I standards and should aim for G standards;
- member States must designate bodies of water and their intended purpose, relating to which water directive it may pertain to;
- a requirement to maintain present quality of water bodies subject to a particular directive;
- creation of competent authorities to oversee the regulation of water bodies.

(Sunkins, 2002)

1976 saw two of the most important water directives being published, the Dangerous Substances Directive 76/464 and the Bathing Waters Directive 76/160. The Dangerous Substances Directive was developed as a framework directive to reduce pollution of all European water bodies from specific substances that are particularly dangerous. The Directive is implemented through two lists of substances called List 1 and List 2. They are

also referred to as black and grey lists, the former have specific daughter directives due to the effect that they may have on the environment; for example Mercury (EC, 1982) and Cadmium (EC, 1983). All substances on both lists require prior authorisation before release into the environment by competent authorities (EC, 1976a).

The Bathing Water Directive 1976/160 was enacted to protect citizens' health and protect the environment by reducing pollution in bathing waters and preventing further deterioration in those waters, and is a water quality directive. Bathing waters are defined as 'all running or still fresh waters or parts thereof and sea water, in which bathing is explicitly authorized by the competent authorities of each Member State, or bathing is not prohibited and is traditionally practised by a large number of bathers' (EC, 1976).

To protect citizens' health, a 19-point scientific assessment contained within the Directive was developed and was divided into 3 parameters:

- microbiological;
- physico-chemical;
- other substances that may highlight pollution.

The Directive works on the same basis as the other water quality directives, whereby there is an I and G status to achieve, and has led to considerable improvement in bathing waters (SEPA, 2003), through Member States' actions to limit pollution. This has led to a reduction in the risk of exposure to gastro-intestinal diseases that can be contracted through bathing in bathing waters (WHO, 2001). In 1993 the Commission took legal action against the United Kingdom for repeated failures of the Bathing Water Directive at Blackpool and Southend, with proposed fines of £67,000 per day (ECJ, 1993).

In 1987 the status of environmental policy was changed for ever, with the advent of the fourth EAP (EC, 1987) and the Single European Act (SEA) (EC, 1987a) which led to new directions for Europe and its environment.

The SEA, which was established primarily to develop a single European market, also managed to establish a legal basis for environmental policy in the EC Treaty, by devoting a chapter to it (Brenton, 1994). Articles 130R-130T were inserted into the Treaty of Rome, by articles 174-6 of the SEA, further to this, Article 100A stated actions that lead to further

completion of the environmental market, should set a high level of environmental protection as its base (EC, 1987a).

The 4th EAP (1987-1992) differed from previous programmes; the emphasis changed to realise the views of the citizens and industries of the community. Three new themes were developed in the 4th EAP and addressed environmental management.

These three new ideas were:

1. sufficiently strict environmental standards;
2. importance of implementation (formal and practical) and enforcement of legislation;
3. incorporating the current monitoring systems with public information and education.

(EC, 1987).

These new ideas helped to clarify European environmental policy and to develop lucidity with regard to prompt implementation and stricter enforcement, which may not have happened in previous years (EC, 1987) and is still an issue today.

2.4.2 The Second Wave

In 1988 at the Frankfurt ministerial seminar on water it was established that there were areas of water policy that could be improved and that there was a need to address the ecological status of water bodies; and so started the "second wave" of European water law (Aubin and Varone, 2002).

The community's response to this seminar was a call for a Council resolution to improve ecological status of surface waters (EC, 1988), which led to the launch of 4 directives through the 1990s aimed at improving ecological status:

- the Urban Waste Water Treatment Directive (UWWT) 91/271;
- the Nitrates Directive 91/676;
- updated Drinking Water Directive 98/83;
- Directive for Integrated Pollution and Prevention Control (IPPC) 96/61.

The Urban Waste Water Treatment Directive (UWWT) 91/271 is an ambitious directive aimed at reducing the harmful effects of inadequately treated urban wastewater discharges from entering water bodies. Every residential settlement over a population of 2000 has to have wastewater treatment systems provided, with every settlement over 4000 having to achieve secondary treatment of wastewater by the 31st December 2000. This Directive has led to massive capital investment (£9.2 billion in England and Wales alone (DEFRA, 2002a)) in Member States' wastewater treatment systems. This has been a crucial step in achieving enhanced water quality throughout Europe's rivers, lakes and bathing waters for a range of other directives that are directly linked to urban wastewater discharges.

The Nitrates Directive controls the discharge of nitrates from agricultural sources, which is the main source of nitrate pollution within the EC, and occurs when run-off caused by precipitation carries fertilisers into water bodies, which can lead to eutrophication. This Directive along with the Drinking Water Directive 98/83 has sought to control the effects of the Common Agricultural Policy (CAP), which encourages farmers to use more nitrates-based fertilisers to increase yields (Sunkins, 2002). While it is recognised that diffuse pollution is the major cause of failure to comply with European water directives (WHO, 2001) it is still critical that measures are taken to restrict the effect of point source discharges.

IPPC aims at reducing the effect of industry on air, land and water instead of using a multitude of directives that can be chosen by the member state as best fitting for their purposes. In 1992 the Maastricht Treaty (Treaty of the European Union), went further in integrating environmental issues into the working ethos of the EEC by:

- replacing Article 2 of the Treaty of Rome to include explicit regard to the importance of the environment and the link it has to economic development;
- updating Article 3 to include new activities of the community including developing a policy in the area of the environment;
- a declaration to assess impact of the community on the environment;
- dedicated title to environment (XVI).

(EC, 1993)

In 1997 the Amsterdam Treaty (EC, 1997) sought to provide stronger guarantees than given by the Single Act and the Treaty on European Union by inserting the concept of sustainable development plus a new article in the Treaty establishing the European Community. Article 6 contained a passage calling for environmental protection requirements to be incorporated into the designation and operation of other policies. This was previously enclosed in Article 174 (ex Article 130r). The new article also cited such integration as a means of promoting sustainable development. Also in the final acts and declarations, Declaration 12 notes that 'the Commission will undertake to prepare environmental impact assessment studies when making proposals which may have significant environmental implications' (EC, 1997).

2.4.3 The Third Wave

In 2000 the EC launched its most detailed and most ambitious environmental legislation, the Water Framework Directive (WFD), and for the first time encompassed all of the Member States water bodies, with the aim of achieving good water quality status across the community (EC, 2000). The need for integrated water management was first realised at Frankfurt in 1988 (EC, 1988), and further at a ministerial seminar in The Hague on groundwater in 1991, where the need for maintained quality and quantity of drinking water was realised. In 1995 the recently formed European Environmental Agency (EEA) published their report on the environment in Europe and agreed with the need for action. Also in 1995, the Council requested an action programme for groundwater and a revision of the Protection of Groundwater Against Pollution Directive 80/68 (EC, 1995). In 1996, the EC held a two-day water conference which was attended by 250 delegates from Member States' governments, competent and local authorities, industry, Non-Governmental Organisations (NGOs) and individuals to define what the key issues to the stakeholders were; these are highlighted below:

- water management based on river basins;
- "combined approach" of emission limit values and quality standards;
- getting the prices right;
- getting the citizen involved more closely;
- streamlining legislation.

The Commission's proposal for the WFD was published in 1997, and after three years of debate and consultation with the European Council and Parliament it was published and came into force on the 22nd December 2000. With a commitment to streamlining the Community's effective but vast water legislation, five first wave directives (fresh water quality; the fish water, shellfish water, and groundwater directives and the directive on dangerous substances discharges) are to be repealed under the WFD. With its guiding vision of good ecological status as well as specific standards, it paves the way for integrated management of water bodies throughout Europe.

Ecological Status of a water body is a descriptor as to how much human interaction has altered the structure and functioning of aquatic plant and animal communities. Whereas before water quality was scored only according to Emission Limit Values (ELVs) of certain chemicals, such as with the black and grey lists discussed previously, the WFD also addresses ecological communities and how they are populated and affected by the overall water body as a homologue and not just against specific chemicals. This approach gives a greater appreciation of the complexities of pollutant mixing and the complex characteristics of water bodies.

In 2000 after similar debates, the Commission launched a communication to update another first wave directive, the venerable Bathing Water Directive 76/160, which had played an important role in protecting citizens' health and improving water quality for 24 years.

2.5 THE BATHING WATER DIRECTIVE: PROGRESSION OF THE THIRD WAVE

Before 2000, there were two attempts to update the Bathing Water Directive. In 1994 the Council proposed an amended Directive on the quality of bathing water 94/36 (EC, 1994) with strong emphasis placed on the advances in science and technology, public involvement and enhanced management of bathing waters. This proposal was in line with the development of the community's 5th EAP (1993-2000, enacted through 6th EAP) and stated that bathing waters are a major component of the tourism sector in Europe. The Economic and Social Committee (ESC) and the Committee of Regions (COR) gave favourable opinions to the proposal with limited remarks including:

- the over simplification of the microbiological parameters, which may present a risk to human health;
- the risk of incorrectly applying legislation that may lead to further degradation;
- welcomes more public involvement;
- differing quality grades of bathing waters could affect competition laws in the EC;
- cost effects that are detailed as minor in the proposal, may be affected by the introduction of faecal streptococci imperative standards, due to its greater survival rates in bathing water.

(ESC, 1994 & COR, 1995)

The 1994 proposal was then presented to the European Parliament (EP) for its 1st Reading, where, after 10 pages of amendments were voted in and the EP approved the proposal, was then sent to the Commission to continue the cooperation procedure (EP, 1997). In 1997, the Commission released the amended proposal, and it was at this stage that the recent development of the Bathing Water Directive was halted; this was due to Member States not being able to agree on higher biological standards (HOL, 2003).

In 2000, the communication from the Commission to the European Parliament set out to consult with the largest number of stakeholders, including Member States' governments, competent authorities, NGOs and individuals, before publishing a new proposal for the revision of the Bathing Water Directive in 2002 (EC, 2000a). The communication was seen as a skeleton to further legislation and did not aim to present a complete system of bathing water protection, but instead set out five principles that underlined the revision:

1. Water Quality standards are indispensable - they have to be ambitious and legally binding;

    a. Standards have to be realistic, zero-risk cannot be guaranteed;

    b. By minimising the regular risk of human activity, unexpected pollution impacts can be reduced;

2. Bathing Water quality management is not just a matter of monitoring;

    a. It is necessary to have a full understanding of all the processes involved in determining water quality and its variability;

    b. It is important to look beyond what is happening in the immediate vicinity of a bathing area and take into account the use of the hinterland and discharges upstream etc;

3. It is more than ever necessary to have good quality information in near real-time for bathing areas;

    a. Such information is needed by the public to make informed choices about if and where to bathe;

    b. It is also needed by competent authorities to make long-term decisions about water quality management;

4. Bathing water quality management;

    a. Defining what exactly is meant by bathing waters;

    b. Compliance - formal obligations for immediate action and within a certain timeframe;

    c. Developing beach profiles- describing, quantifying understanding pollution sources;

    d. Trends in water quality- bathing water status based on three seasons of data not one;

    e. Standard setting and methods of analysis - what levels should be set for microbiological parameters;

f. Obligation to take action - the existing Directive does not include any obligation to act or react to bathing water deterioration;

g. Prediction of water quality - bathing water managers should develop a predictive approach suited for their bathing water;

h. Information requirements, public participation and reporting - Active dissemination of information to the public;

i. Keeping the Bathing Water Directive up-to-date - using a management committee to change technical and scientific provisions based on the best available information, rather than having to wait 25 years for changes;

5. Adjusting the scope of the new Bathing Water Directive away from a results only Directive;

a. Actively tackling pollution sources;

b. Close integration with the Water Framework Directive.

(EC, 2000a)

On the 8th March 2001, the Council published its conclusions on the Commission's communication to update the Bathing Water Directive, and proposed a course of action, for furthering the formation of the Directive. The main points that were raised by the Council were the need for cost/benefit studies and the development of a sound scientific basis. There was also need to clarify the relationship between the Bathing Water Directive and others such as the Water Framework Directive. In line with the Commission's communication, better definitions of bathing water terms, harmonisation of analytical methods and up-to-date information dissemination were requested (EU, 2001). On the 3rd May 2002 the European Parliament and Council released the 6th EAP in which a commitment to revise the Bathing Water Directive was integrated (EC, 2002b), and on the 24th October 2002, this commitment was realised with the publication of COM (2002) 581 2002/0254 (COD), a proposal for a Directive of the European Parliament and of the Council concerning the quality of bathing water (EC, 2002).

The review in the first part of this chapter is presented to show how European policy and law has changed to embrace the environment. This informs the research, giving a vital understanding of how groundbreaking the WFD and subsequent third wave directives are. By using a measure of ecological status and using a holistic viewpoint, the EC is actively protecting the water quality, rather than attempting to use end of the pipe measures such as were used during the time of the inception of the first BWD in the 1970s.

2.6 EVALUATING THE CONCILIATION PROCESS FOR COM 581

The next section briefly describes the process to deliver a new Bathing Water Directive based on COM581 and is structured chronologically around key events such as Parliamentary readings and co-decisions procedures, using the largest possible range of stakeholder input. This is vital in understanding how the new Directive will be delivered and how the various stakeholder inputs ultimately shape the Directive.

2.6.1 COM 581

Based on the ambitious consultation process of 2000 and with the guidance of the Council, the Commission published COM581 with several overarching goals that they wanted Member States to adopt as highlighted in the original consultation document, namely; ambitious water standards, management of bathing waters and better information to citizens (EC, 2002). These goals were delivered in key articles as prescribed in COM581.

The Commission based on World Health Organisation (WHO) research by Kay et al. (1994) into risk associated with Bathing Waters reformed the microbiological parameters from the original Directive and reduced the number of overall assessment parameters which also include physical and chemical parameters from nineteen to two, which were proposed as most significant to human health. These two new microbiological parameters Escherichia coli and Intestinal enterococci replace three microbiological parameters; Total Coliforms, Faecal Coliforms and Faecal Streptococci which have come under increasing pressure of their representation of human risk (Kay et al., 2005). The levels for the two new parameters are in Table 4 with 'Good' quality representing a 5% chance of people contracting gastro-enteritis when using bathing waters. This compares with 12-15% risk of contracting gastro-enteritis from the original 1976 'Imperative' standard, the equivalent to 'Good' in the revised Directive. These standards are discussed in Article 4 and detailed in Annex I of COM 581. These are also shown in Table 4.

Table 4 - Original 'Excellent' and Good' standards proposed for bathing waters

Microbiological Parameters	**Excellent Quality (guide)**	**Good Quality (obligatory)**
Intestinal Enterococci (I.E.)	100	200
Escherichia Coli (E.C.) in cfu/ 100 ml	250	500

Article 6 proposes the creation of a Bathing Water Profile (BWP), which aims to assess the physiological, geographical and hydrological characteristics of the bathing waters, the impact of all sources of pollution both qualitative and quantitative and an assessment of how well the prescribed monitoring of the bathing water is representative of the risk posed to recreational water users such as surfers and canoeists. This requirement furthers the need for Member States to develop new methodologies and ways of thinking in their assessment of the water bodies under their control.

This approach established in the WFD aims to assess the water body in terms of ecological status and ecological potential and is not only reliant on pass/fail quality standards as in previous EU legislation. Annex II and VII of the WFD describes various wide ranging monitoring requirements that are to be carried out, especially in 'protected waters' of which bathing waters are designated (EC, 2000). The Bathing Water Profile is in line with the Water Framework Directive, whereby river basins are characterised in similar ways. See Article 5 of the WFD for further information (EC, 2000).

Since the original Bathing Water Directive was launched in 1976, the public has become increasingly aware of their environment and the effects that they can have on it. Indeed 65% of Europeans believe that they can make a change to their environment, with 45% of Europeans believing that greater access to information is key to improving the environment (EU, 2003a; EC, 2008). In previous attempts to revise the Bathing Water Directive (EC, 1994,1997a) there were calls for greater public communication, however these revisions failed on scientific guidelines and it was not until the 1998 UN-ECE Aarhus convention on Access to Information and Public Participation in Decision Making that a commitment to information to the public was fully established (EC, 1998).

Communication to the public has moved on greatly from the original Bathing Water Directive, in which there was brief mention of delivering 'objective information' to the public (EC, 1976). COM 581 in contrast has dedicated no less than 40% of all proposals to informing the public, with Article Sixteen enshrining this issue (EC, 2002). However, there is much work to do as Jules Maaten the appointed Rapporteur for the European Parliament on COM581 reports. He found it 'difficult, during his inquiries to find out in less than 10 minutes how good or bad bathing water in Europe is' (Committee on the Environment, Public Health and Consumer policy (EPC), 2003). Further information on how communication has been developed in support of the BWMF can be found in Chapter 4.

Along with these specific articles, COM581 develops various ideas such as increased awareness of watersports enthusiasts whose numbers have swelled in the 30 years since the original Directive and who may not be covered by the existing sampling regimes. Also covered is the need to address emergency planning for incidents such as oils spills, transboundary co-operation between member states and the need to harmonise the whole process of sampling, reporting and notification to the public. All of these new ideas and directions require substantial resources from Member States and as such COM581 was subject to fierce scrutiny by all stakeholders.

To evaluate the proposal, the European Parliament on the 7th November 2002 appointed the EPC as the responsible committee (EPC, 2003) and they in turn appointed Jules Maaten as Rapporteur on the 27th November 2002 (EPC, 2003). The Committee on Legal Affairs and the Internal Market (LAIM), the Committee on Regional Policy (COR) and the Committee of Regional Policy, Transport and Tourism (RTT) were also consulted for their opinions (EPC, 2003). Along with these Parliament-based activities, the Council, several competent authorities and independent bodies developed opinions on the proposal.

2.6.2 First Impressions

The first response from within the EC came from the European Economic and Social Committee (ESC) in response to consultation from the Council. The Committee agreed that a revision of the Bathing Water Directive and the repealing of the original 1976 Directive was valid and agreed with a need to update the analytical methods to bring this in line with current scientific knowledge and practice and also the change in policy such as the Water Framework Directive.

A key point raised in the response was the broadness of the proposed Bathing Water Profiles, whereby Member States would have to provide information on all sources of pollution affecting bathing waters. This was thought to be unrealistic and the committee suggested only focusing on the main sources of pollution affecting the bathing water as this could prove excessive in cost and time, of which the committee also argued that the overall Directive had not been evaluated effectively in this manner either (ESC, 2003). This was also of great concern to the UK Department for Environment and Rural Affairs (DEFRA) when they conducted a cost-benefit analysis (DEFRA, 2002) prior to the finalisation of COM 581. This stated that the cost to England and Wales of complying with COM581 would be up to £7.3 billion a year. This figure, as stated in the report itself, hinges on large assumptions with issues such as the cost of diffuse pollution treatment, of which only one study was conducted. Also the report was created before the publication of COM 581, which occurred 5 months later. This means that this DEFRA report should be treated with the utmost critical review before acting on its contents, a view supported by its author Dr. Kieran Conlan at a conference in May 2003 (Conlan, 2003).

The ESC also commented that the Directive should be limited only to bathers and not to include recreational users who traditionally practice their activities further out to sea, due to the increased chance of submersion and the lack of scientific knowledge on the associated risks of these activities. Finally the committee stated that the public requires above all, 'clear, rapid and frequent information on bathing water quality' (ESC, 2003), which is a critical management method and a goal of the original consultation (c.2 p.23).

The Committee of Regions (COR) and Committee on Regional Policy, Transport and Tourism (RTT) published responses to COM581; the LAIM declined to comment on the communication. The COR stated that the communication was welcome and needed to reflect the changes in science and technology and would significantly improve bathing

water quality. It was even stronger than the ESC in pushing for real-time information to the public, which should be produced in an easily understandable harmonised format that still respected the principle of subsidiarity (COR, 2003). In common with the ESC, the COR asked for further analysis of costs of the communication. COR presented a positive approach when questioning the benefits to the tourism sector and the local regions that would benefit as a consequence of the communication. With regard to Bathing Water Profiles, the COR stated that they should only be applied to bathing waters classified as poor, due to the apparent excessive measures needed to implement them. The RTT, whilst generally in line with the ESC and COR, was strongly in favour of including recreational users in the Directive arguing that the associated health risks are similar to bathers and that number of watersports enthusiasts within Europe has increased rapidly since the original Directive of 1976, so they need to be protected (RTT, 2003).

Outside of the European mechanism, several stakeholders such as DEFRA, mentioned above, developed opinions on COM 581 at this stage of development as there was still the opportunity for changes and amendments to directives and Member States and other interested stakeholders arguments contained within opinion papers at this stage can help steer the final directions and decisions of directives.

The European Environmental Bureau (EEB), an NGO based within Brussels, welcomed the Directive and believed that Bathing Water Profiles would become an effective management tool in the control of diffuse pollution, which is the primary source of bathing water contamination (Stapleton, 2003) within the UK and other member states. As highlighted in 2.4.2 in this chapter, Members States over the last 15+ years have spent billions of Euros bringing point source pollution under control under a raft of second-wave directives. The new Bathing Water Directive and specifically the Bathing Water Profiles could potentially require as much if not more investment to control diffuse pollution, which is a much harder output to control. The EEB also pushed for the inclusion of recreational users, due to the large increases in numbers.

Within the UK, the House of Lords Select Committee on the European Union reviewed COM 581, with oral evidence received from Rt. Hon. Elliot Morley MP, Minister of State for the Environment and Climate Change and written evidence from the Environment Agency. In their report they state that the UK Government's main concerns lay in the apparent costs in implementing the ambitious Directive, with limited case studies carried

out in its support (HOL, 2003). The area of most concern was diffuse pollution. The UK Government proposed more management measures and flexibility in the standards of water quality, in essence a relaxation of the original Directive and increased monitoring and information to the public on pollution events. This reduces the cost implications. The House of Lords report agreed with the government's assumptions on costs and the lack of cost analysis, as stated previously in this chapter, and believed that the Commission should carry out a far more stringent financial appraisal and cost benefit analysis before the UK could sign up to the proposals as they stood (HOL, 2003).

2.6.3 The Formulation

On the 1st October 2003 the EPC concluded its investigation into the Bathing Waters Directive for the Parliament with the publication of its draft legislative resolution document (EPC, 2003). This contained amendments that the EPC believed should be made to COM 581, with a vote on this document to be carried out in Parliament on the 10th October 2003.

Within the document 36 amendments were mooted; through these the most important message to emerge was the need for an enforceable and workable Directive. The EPC document pushed for the inclusion of monitoring outwith 100 m of the low tide line, in an effort to protect recreational users such as surfers and kayakers. Also, in an attempt to make the Directive more flexible, a new article on transitory contamination, i.e. short time periods where the water quality does not meet the necessary standard, was proposed. However, with this flexibility the EPC also called for increased proactive management in times when the water quality may fail, by developing effective communication to the public through the use of signage and near real-time information on the Internet. If the contamination would pose a threat to bathers then a temporary bathing ban may be enforced. This system is already in place in Belgium where local mayors decide the action in these events (O'Brien et al., 2001). Further to these measures to be adopted in times of pollutant events, the committee proposed a more friendly approach to general bathing water status display using a "smiley face" approach for the quality e.g. smiley ☺ for excellent status and sad face ☹ for a poor quality standard. This approach has now been trialled by the Scottish Environment Protection Agency (SEPA) since 2003, with evidence yet to be ascertained to the effectiveness of this approach; however a survey by Staines (2002) showed that 58.4% of Scottish beach users do not use bathing water data when

deciding whether to go to the beach or not. Finally the largest issue with COM 581 in the opinion of the EPC was the raising of the water quality standards to such a high level that many Member States would fail to achieve them. For example 30% of the Netherlands designated bathing waters would fail to reach the good standard. Under the existing Directive 97% of all coastal bathing waters pass the required standards (EPC, 2003), meaning that there needed to be a compromise in the standards set by the Commission.

The draft legislative resolution was placed to the vote by the Parliament on the 10th October 2003 with 290 in favour, 220 against and 8 abstentions. From here this document was then sent back to the Commission for discussion and possible changes to their original directive proposal (COM 581). On the 5th April 2004, the Commission published a modified legislative proposal that took into account the issues raised by the Parliament and Council. This was then debated by the Parliament and Council again[1].

The Commission accepted most of the amendments proposed by the Parliament, however there were several that they did not want to accept. Amendments accepted in full by the Commission were where they improved COM581 in the areas of public information and management measures. Amendments accepted partially or in principle were in standardised symbols of water quality. However, in the spirit of subsidiarity the Council stated that these should not be forced upon Member States. Also the Commission noted that Bathing Water Profiles should only cover specific issues affecting bathing waters that are not covered in the Water Framework Directive; such issues may arise as the WFD focuses on macro-management of a large area compared to micro-management of bathing waters, where each bathing water is assessed individually. It did not accept amendments covering the inclusion of watersports to within 100 m offshore due to the difficulties of establishing and enforcing such a regime; it also did not accept the amendment of transitory contamination even though it remained open to the concept; a wet weather waiver was employed in the initial Directive (EC, 1976) for a similar issue.

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[1] It should be noted that this document round robin forms the crux of the European legislative formulation and so it can take several years to bring legislation into force.

Throughout 2003 whilst the Parliament was assessing COM 581, the Council was also trying to make sure that the Directive would be workable and not place undue burden on Member States, with regard to the water quality standards and the Directive as a whole. As corroborated by the ESC (ESC, 2003), the Council was unsure of the Cost Benefit Analysis carried out by the Commission for the Directive and they were also unsure of the scientific evidence behind the tightening of the water standards. Further to this, most Member States also objected to the inclusion of recreational users into the Directive due to the additional costs. For example, sewage released into the sea through long outfalls may have to be treated to a greater extent if the Directive's scope was widened in such a way, due to the increased chance of contact.

By December 2003 the Council had still not reconcile these issues and so in an effort to maintain the momentum of the legislative process the Irish Presidency of the EU proposed a revised version of COM581. This was circulated in May 2004, with the following major change; a fourth bathing water classification called 'Sufficient' which would be included with the already described 'Excellent', 'Good' and 'Poor'. In June 2004 the Council unanimously reached political agreement on the revision and in December 2004 published a common position incorporating most of the Parliament's original amendments from their first reading. There were still some issues that the Council had problems, with including primarily the inclusion of recreational users. In January 2005, in an effort to finally push the Directive through, the Commission bowed to the Council's suggestions of a fourth water quality standard so that the original Directive may finally be revised at the third attempt (EC, 2005). The Commission, though now accepting that there may now be a lower bathing water standard than they had envisaged, saw that the positive aspects of enhanced management and information to the public was a worthwhile result of the Directive.

In April 2005, the Parliament carried out a second reading of the Directive, (amended as it had been through the Irish Presidency, Council and Commission and the EPC) and on appraisal of the document were not impressed with the fourth category of quality standard proposed through the Irish Presidency and taken up by the Council. Jules Maaten declared that the Council "lacked ambition, particularly regarding the parameters" (EP, 2005) His viewpoint was shared with the majority of EPC members, and they voted to rescind the fourth category, arguing that it would not improve on the 1976 Directive or meet the minimum standards of the WHO report (WHO, 2001). On the issue of recreational users,

the Parliament decided that their inclusion in the Directive was not justifiable financially, however there should be information to these users on quality. With regard to emergency plans, the Parliament requested detailed surveillance, monitoring and rapid response, with information to the public.

In June of 2005, the Commission responded to the Parliaments' amendments accepting measures with regards to information to the public, the bringing forward of the date for formulation of Bathing Water Profiles and the inclusion of viral monitoring that was present in the original Directive, but had been removed in COM 581. Amendments rejected were to emergency planning arguing that it did not fall within the scope of the Bathing Waters Directive and the definition of transitory contamination being too vague (EC, 2005a).

With seemingly immovable key differences appearing between the Council and the Parliament on such areas as water quality standards and recreational users, the two parties entered conciliation, whereby a single committee containing delegates from both parties attempt to reach agreement on the issue and formulate a Directive acceptable to both. From this committee a joint text was formulated, which was published in early December (CSL/EP, 2005). The Parliament accepted the fourth quality standard of 'sufficient' with the Council accepting that the limit of this standard would be raised. With regards to information, the Council accepted that there is a the need for near real-time information updates via the Internet and the use of EU-wide symbols of water quality status and finally a review of the water quality standards from the Commission to the Parliament to be moved from 2018 to 2008. On the 18th January 2006 at the Parliament's third reading, the Joint text from the conciliation committee was approved by a vote of 582 for, 11 against and 56 abstentions.

This document now represented the final version of the revised Bathing Water Directive and was placed into the Official Journal of the EU in February 2006 (EC, 2006). Due to the confusing nature of European legislative development with the myriad of documents, the next section shall briefly discuss the finalised major articles and ideas, many of which have been mooted throughout the formulation process.

2.7 MAIN ARTICLES, THEMES AND IDEAS TO EMERGE FROM COM 581 AND SUBSEQUENT PROPOSALS

In the pre-amble of the Directive, there are references to the pursuit of appropriate timely information to citizens, with regard bathing water quality status, predictable short-term pollution and data allowing easy comparison across all EU Bathing Waters, a comparison not available to Jules Maaten near the beginning of the Directive formulation in late 2003 (EPC, 2003). The issue of public access to information was strengthened with the ratification of the Aarhus Convention in February 2005 (UNECE, 2005).

To achieve these informational goals, Article 11 of the Directive encourages public participation with the 'establishment, review and updating of lists of bathing waters' (EC, 2006), with Competent Authorities expected to take full account of any information offered. Article 12 is dedicated to the provision of information to the public and requires a number of inter-related outputs for each Bathing Water, namely; current bathing water classification and clear prohibition or advisory notices in the case of unfit water, a general description of the Bathing Water in accordance with the Bathing Water Profile which is detailed in Annex III, notification of short-term pollution, information on abnormal events and an indication of further information sources, if required. Outwith the Bathing Water, on the Internet, Member States and their Competent Authorities have to produce a list of all their bathing waters and their corresponding quality status over the last 3 years, measures to be taken if water quality is poor and short-term pollution information. Where possible this information will be supplied using 'geo-referenced technology' (EC, 2006).

In an effort to maintain the push for active management of Bathing Waters the Directive also notes in the pre-amble that Bathing Water Profiles should be used to better understand risks and the management measures needed to combat them. This is verified in Article 6 in the Directive. This was seen as crucial to the Commission but strongly contested by the Council on grounds of costs. The Bathing Water Profile as much as possible shall use information that has already been gathered by the Water Framework Directive, however as stated earlier in this chapter (section 2.6.1) there are issues regarding scale, namely macro versus micro management. To this end Annex IIII details all information required in a Bathing Water Profile and is very similar to the initial proposal in COM 581.

There shall be four microbiological quality standards 'Poor', 'Sufficient', 'Good' and Excellent, with Table 5 showing the parameters required for these. Poor water quality is a failure to achieve the at least 'Sufficient' water quality. The need for this is encapsulated in Articles 4 and 5 of the Directive.

Table 5 - Microbiological Parameters for Bathing Water Quality status

	A	**B**	**C**
Parameter	**Excellent Quality**	**Good Quality**	**Sufficient**
Intestinal enterococci (cfu/100ml)	100	200	185
Escherichia coli (cfu/100ml)	250	500	500

2.7.1 Conclusion

From this law review it can be seen that the key changes from the first Bathing Water Directive are in the use of active management systems, deployed information to the public and Bathing Water Profiles. There has also been a refinement of the microbiological methods needed and the need for greater awareness of all pollution affecting Bathing Waters, thus creating the need for the development of other monitoring methods to be used as well as the prescribed microbiological methods.

This Directive drives the research and so it is important to have a clear idea of how this will ultimately work. Throughout the other chapters, work has been guided through not only the initial COM 581 document but also by the whole legislative and policy framework that exists in European law, which has been demonstrated in this chapter. This enables the development of the framework enabling competent authorities to have the tools needed to implement the Directive effectively. The requirements in the finalised articles in the revised BWD 2006/7 are delivered through the BWMF which was developed to support these and is shown in the other chapters of this thesis, with particular regard to Chapter 5.

This presents a 'live' test of these requirements to assess how successful the BWMF was in achieving these.

The first part of the review that established the historical formation and formulation of EC and the development of the green movement in the Europe and the rest of the world is important for the other chapters as it shows that the European mechanism is complex and that the principle of subsidiarity is crucial to the successful workings of European law. The practical applications and approaches developed for the UK in chapters three and four of this thesis would be less useful as this is driven by an understanding arising during the consultation process. This allows the underlying ethos of environmental law to come to the fore.

The 'greening' of European law enabled the development of management approaches that are described in the revised Bathing Water Directive. Understanding the Directive is at the heart of the Framework in chapter five and sets good precedents for development of biological monitoring methods in Chapter 3. The EU shift towards a holistic management approach is shown throughout the review from 1988's Frankfurt meeting of ministers to the publication of the finalised Directive in 2006. This resonates throughout all the chapters. Without this holistic undertone then no framework would be needed.

Linked to this is the increased engagement of European citizens in the environment. In the review this is highlighted in various ways such as the 6th EAP, Aarhus, the Eurobarometer studies and the way that the ESC and COR recommended better information in the 1994 proposal. Understanding this great push for engagement with and by citizens allowed the whole communication strategy to be developed, as shown in Chapter 4. Consequently the law review enables the creation of appropriate communications systems, safe in the knowledge that there is precedent and need for them.

To conclude, the law review enabled the researcher to understand the parameters fully in which the framework and its components could operate successfully. Without this knowledge any outputs from the research could be limited, suggesting that the interdisciplinary approach can work. The proof of the benefits of interdisciplinary research is to examine how the findings of this chapter can integrate with the other chapters and their disciplines in the remainder of the thesis. This ultimately should answer the conceptual question of the aim.

CHAPTER THREE- EVALUATING BIOLOGICAL INDICATORS FOR THEIR SUITABILITY IN THE REGULATION OF BATHING WATERS

3.0 PURPOSE OF THE CHAPTER

Chapter 2 showed that there is a need for a holistic approach to bathing water quality. Whereas before a pass/fail system based on microbiological standards was used, there is now a need to gain understanding of the factors affecting bathing waters. Specifically pollutant risks posed through local outputs. To understand the effects of these pollutants and to provide data in support of the BWPs, effective monitoring of the bathing water needs to be carried out.

The purpose of this chapter is to review biological monitoring of water to find the most suitable methods for The Bathing Water Framework. Starting with a literature review of available methods and how these may fit within a regulatory regime, the chapter goes on to show how the methods were evaluated, before concluding with details of the pilot study carried out to test the chosen methods.

3.1 INTRODUCTION

As stated in Chapter 2, the third wave of European water policy has bought about a significant shift in scientific and technical approaches, from the simple parametric compliance approach (Lister, 1996, EC, 1975). As stated in Frankfurt (EC, 1988) there was a realisation that the ecological status of water bodies was key in developing water bodies and this led to a raft of 4 directives aimed at removing various major pollutants including wastewater (EC, 1991), nitrates (EC, 1991a) and industrial inputs (EC, 1996).

This change in approach eventually led to the Water Framework Directive and the proposal for an updated Bathing Water Directive, COM 581. Both of these directives grasp the need to assess all processes that may affect a water body (EC, 2000, EC, 2000a).

With these new processes comes the need for new tools and methodologies that can fulfil obligations set down in the Water Framework Directive and which are applicable to the Bathing Water Directive explicitly. Predicting risk to anthropological and ecological water quality requires long term monitoring systems that will be resilient to *in situ* conditions in the bathing waters (Salazar & Salazar, 2000).

An array of analytical techniques exist that can be used to detect pollutants in any given ecosystem, using biological, chemical and physical methods. This area or study is called ecotoxicology; the term first used by René Truhaut in 1969 (Truhaut, 1977).

3.2 LITERATURE REVIEW

This literature review in this chapter shall address the following issues:

- ecotoxicology and how it has developed from its inception in the late 1960s;
- what criteria do methods for in situ bathing water monitoring need to satisfy;
- how to deploy the chosen methods to the bathing water.

3.2.1 Ecotoxicology and How It Has Developed From Its Inception in the Late 1960s

Informed toxicology first appeared in its most basic form with Greek and Roman civilisations having knowledge of specific poisons and the antidotes, a well-known example being when the philosopher Socrates was sentenced to death by drinking hemlock after being found guilty of refusing to recognise the gods recognised by the state and of corrupting the youth (Jowett, 1892).

Ecological toxicology, however, is a much newer discipline that first came about with the progression of the green movement in 1960s, as detailed in Chapter 2, Section 2.3. The word Ecotoxicology was first defined by Dr. Rene Truhaut in 1969 as "the branch of toxicology concerned with the study of toxic effects, caused by natural or synthetic pollutants, to the constituents of ecosystems, animal (including human), vegetable and microbial, in an integral context" (Truhaut, 1977).

Ecotoxicology and toxicology in general is the study of the effects of chemicals on organisms and this been historically developed through the dose-response relationship (Ballantyne, 1999, Wright & Welbourn, 2002, Goldstein et al., 1974).

This system has been extensively applied to the pharmaceutical industry to establish safety measures and correct dosages for pharmaceuticals. To achieve a dose-response relationship a genetically homogenous test population, such as cloned mice in the pharmaceutical industry, are given a particular dose and the response predominantly mortality, is recorded and a sigmoidal curve graph plotted as shown in Figure 4 (Walker, 1996).

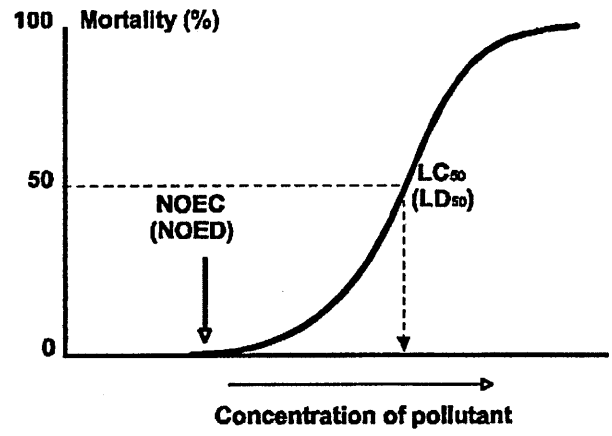

Figure 4 - Dose- Response Curve for non-carcinogenic substance

In measuring response, there are two major data points to consider; the NOEC level and the LD50/LD50. NOEC is the No Observable Effects Concentration whereby the dose of the chemical has no effect on the test organism or population. The LD50/LC50 or EC50 is the level of concentration where there is a 50% effect on the test organisms. LD and LC are defined as Lethal Dose and Lethal Concentration respectively. EC50 is a far more subtle index and refers to when 50% of the population is affected (Ballantyne, 1999). This method of gauging chemicals and their effects on the environment was a popular tool in the early days of ecotoxicology, due to the apparently powerful and simplistic relationship exhibited. It still forms the backbone of contemporary pharmacological research (Liston et al., 2004, Cheng and Lai, 2003).

To understand why dose-response developed in the early stages of ecotoxicology it is necessary to understand how the environment and the protection of it were seen. Figure 5 shows a model from Schüürmann and Markert (1998) that highlights how the environment and man's interactions and management were perceived in the 1970s. It can be seen that it is much simplified from contemporary models of the perceived interactions, as shown in Figure 6 (Schüürmann & Markert, 1998).

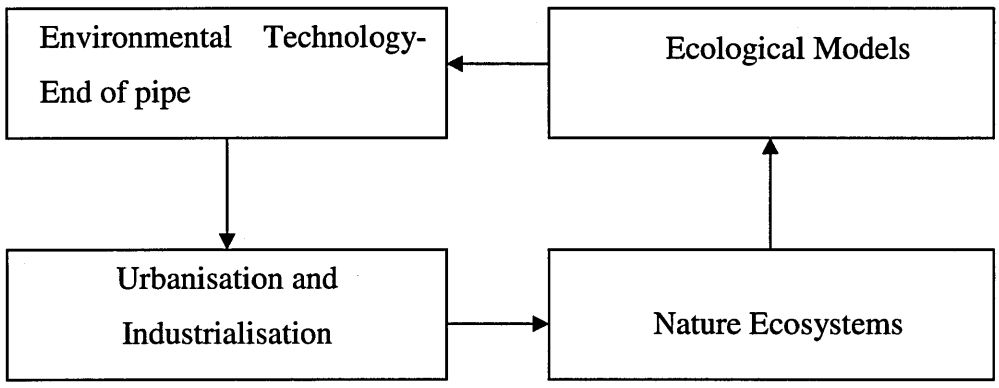

Figure 5 - Model of 1970s perception of environment and management thereof

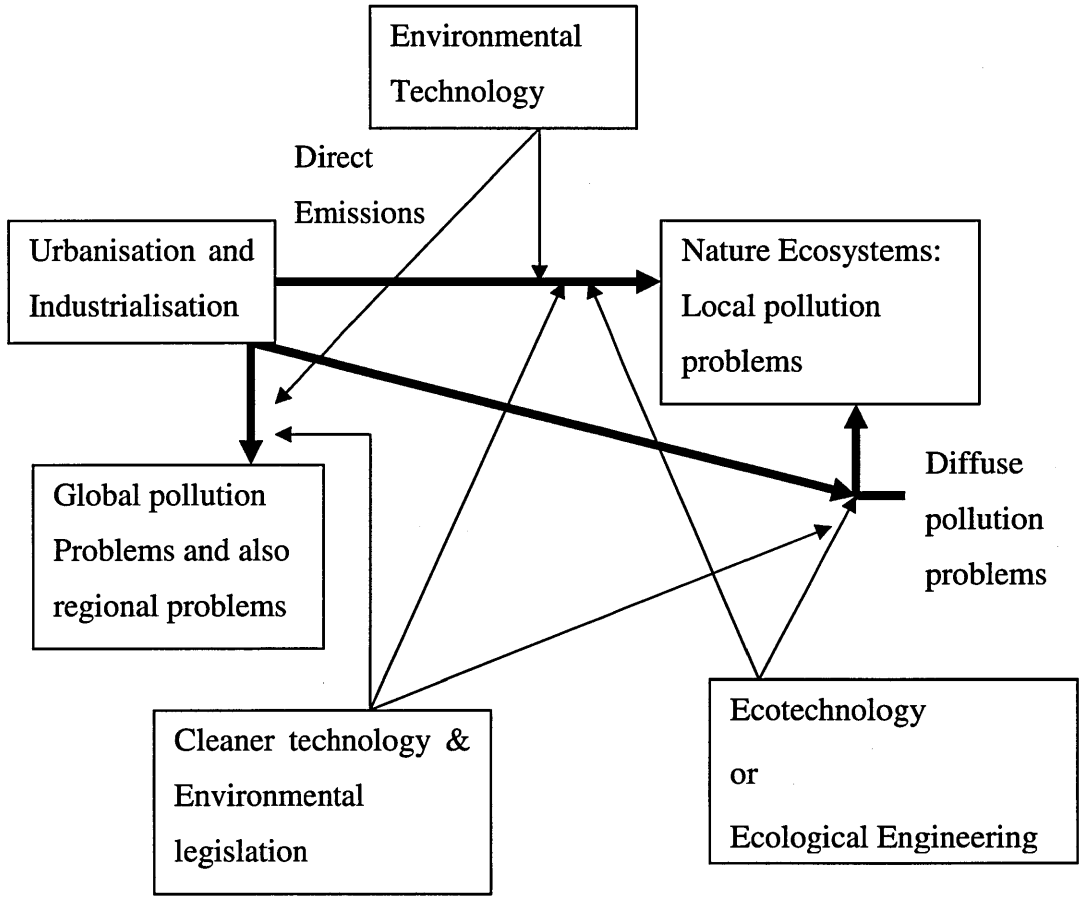

Figure 6 - Model of contemporary (1998) evaluation of the environment and the management thereof

In the 1970s and 1980s, the Single-Species Acute Toxicity Test was the primary method for eliciting the dose-response relationship and the quantification of the damage that it may cause to an ecosystem. Sprague, a proponent of these bioassays stated in a review paper (Buikema et al., 1982) 'that LC50 (lethal concentration for 50 per cent of individuals on long exposure) is recommended as the most useful single criterion of toxicity'.

Linked with this, traditional systems of chemical detection involve the measuring of compounds in air, water and soil and whole organisms to establish if toxic residue is present in the ecosystem. This is a critical area of toxicology which determines the presence of the chemical and can be established by using various chemical analyses such as High Pressure Liquid Chromatography (HPLC) and Mass Spectrometry. However, these systems, because they rely on latent effects such as fauna or flora mortality or degradation only give a brief glimpse into the effect of the chemical and only on the organism tested. This does not reflect *in situ* conditions where many chemicals exist and which may be additive, synergistic or reductive to each other. Furthermore climatic conditions may lead to the chosen sample area having high concentrations of chemical compared to the rest of the ecosystem (McCarthy & Shugart, 1990).

Bioindication on the other hand, is the use of an organism (a part of an organism or a society of organisms) to obtain information on the quality of its environment. Organisms which are able to give information on their environment are bioindicators (Wittig, 1993). Bioindicator systems have an advantage over traditional systems which only provide a snapshot of chemical ecosystem health, as they can show how the chemical actually affects the organism in terms of organ, cellular and genetic damage.

Bioindicator methodologies use data collected from biomarkers to establish the health of populations and the ecosystems that they form part of; biomarkers were first defined as 'the product of the interaction between a target cell or molecule and a foreign substance' (NAS, 1989). There has been much debate over the definition of biomarkers and what it means for bioindicator research (Peakall, 1994). This research uses the following definition of biomarkers: 'functional measures of exposure to stressors, which are expressed at the sub-organismal, physiological or behavioural level' (McCarty and Nunkittrick, 1996).

Biomarkers were originally developed as a medical application to study the effects of compounds on human tissues, in such areas as oncology. One of the first biomarkers methods to be used in ecotoxicology was the Neutral Red Retention Assay (NRR) (Borenfreunder & Puerner, 1984). Originally developed to assess carcinogenic cell membrane damage in humans, it was adapted to test cell membrane damage in other organisms and is a key indicator of chemical interactions (Lowe et al., 1995; Martinez-Gomez, 2008).

Biomarkers are a good choice for the Bathing Water Directive as there are a large variety of test species around the coastline of the United Kingdom (Gosling, 1992). Biomarker assays are relatively cheap in both money and time compared to traditional analyses and can be used over long periods of time to develop knowledge of ecological risks and trends that may threaten the water quality of bathing waters. *Mytilus edulis,* the common or blue mussel, for example, has been used from the Arctic to Australasia as a biomarker for over 20 years with great success (Salazar and Salazar, 2000; Steinert et al., 1998; Catherino et al., 2008). Due to the availability of various biomarkers over various levels of biological organisation there are subsequently many methods to choose from within this field. To choose the most appropriate methods, it is important to understand the needs of the research and how this affects the parameters that the methods need to conform to. As such the next section of the review details the issues that need to be considered when designing the biomonitoring.

3.2.2 What Criteria Do Methods For In Situ Bathing Water Monitoring Need To Satisfy?

To define what methods may be useful, it is important to realise what is required within the Directive as without this awareness any methods developed, even if they are extremely effective, may not fulfil legislative requirements and may thus not be available for use within the Framework, which is of course the ultimate goal. Within the Directive under the auspices of the Bathing Water Profile prescribed in Article 6 there is a need for:

- an identification – quantitative and qualitative - of all potential sources of pollution;
- an assessment of their potential to pollute bathing water, thus impairing the health of bathers. This assessment should be made, in terms of time - acute or chronic risk potential, - in terms of the nature and volume of all polluting and potentially

polluting discharges; and their effects assessed in terms of distance from the bathing water (EC, 2002).

This requirement for pollution information is wide-ranging and extensive, however there are key questions raised from this that help to define suitable methods for the monitoring of the bathing water:

- what are the time periods of the pollution and what are related health effects?;
- what are the sources of pollution within the bathing water?;
- what quantitative and qualitative methods can be used to generate a picture of water quality and ecological status?;
- how does the nature of complex mixtures rather than single compounds affect bathing water quality and ecological status?

Within ecotoxicological monitoring, exposure to a certain substance or substances and how quick a response to a prescribed endpoint is, defines the type of toxicity that is to be measured. There are three well established time periods of toxicity test that are defined by Paine and Marr in 'General and Applied Toxicology' (Ballantyne, 1999) as;

- **acute toxicity** occurring from single dose of substance given within 24 hours, with adverse effects occurring within a short time typically up to a maximum of 14 days;
- **sub-acute/sub-chronic toxicity** multiple doses of substance given daily for not more than 10% of the animal lifespan. **Sub-acute** studies typically 14, 21 or 28 days, **Sub-Chronic** typically 90 days in rats;
- **chronic toxicity** are studies carried out over most or all of a test organisms life time and result from continuous long-term low concentration substance exposure.

To better understand the different toxicity tests Table 6 gives examples of everyday toxic exposures using both anthropogenic examples and examples relevant to the research.

Table 6 - Toxicity tests and everyday examples of anthropogenic and research relevant exposures

Toxicity Test	Anthropogenic Exposure	Research relevant exposure
Acute	Accidental Catastrophes, overdoses of suicides (Ballantyne, 1999)	Oil Spills such as the MV Transporter (See Ansari and Ingole, 2002) Sea Empress (Lyons, 1999)
Sub-Acute/ Sub-Chronic	Workplace and domestic chemicals, therapeutic agents (Ballantyne, 1999)	Lower dose levels relative to accidental exposure levels, Landfill leachate (Bloor and Banks, 2005)
Chronic	Daily ingestion of food additives or pesticide residues in food (Ballantyne, 1999)	Low level concentrations with prolonged exposure, Tributylin induced imposex in dog whelks (Hodgson and Levi, 1997)

The requirements of the Directive pose a dilemma as to the choice of time period due to the need of both acute and chronic risk potential. As part of this need, joint research was carried out with SEPA (SEPA, 2004a) to identify pollutant entrainment within the river catchments that enter the bathing water at Arbroath. This research helped to answer chronic issues and also addressed acute issues occurring upstream. Acute toxicity understanding was also aided by telemetry linked to wastewater outfalls that spill into the bathing waters. Whenever there was a spill, date, time and volume of spill was sent to the researcher, by United Utilities PLC. Further details of this can be found in Chapter 5.

It can be stated that methods need to work within a sub-acute/sub-chronic time period, which involves typical time periods of 14, 21 or 28 days. From this it was decided to carry out 28 day cycles of tests, this being most appropriate to the Directive requirements (EC, 2002). Further to the defined time period of toxicity exposure, it is important to address parameters for which the methods exist, i.e. within a regulatory framework. As such the methods need to be straightforward to perform and rapid due to the fact that results will be

required throughout the bathing season and for a number of locations (Smolders et al., 2003, Galloway et al., 2004).

The time period of exposure establishes the type or methods that could be used; however the research also needs to reflect how best to monitor for pollutants and their possible effects. Due to the wide scope of possibilities defined by the BWP, it is important early on to choose appropriate parameters.

With the period of exposure determined, the sources of pollutants affecting bathing waters are the next consideration. This is a key aspect of the Directive and one of the areas where an integrated management approach is needed (EC, 2002a). There are many sources of pollution that can affect bathing waters and locating them is a considerable task.

There are two main types of pollutant source; diffuse and point. Point source pollutants can be traced back to a single point of origin such as a wastewater treatment plant outfall or industrial process. Diffuse pollution cannot be traced back easily to a single point of origin, such as agricultural run-off (Stapleton et al., 2003).

Prior to the second wave of European water policy, wastewater outfalls were the predominant point source pollution affecting coastal waters (Matthiessen and Law, 2002). These are now highly regulated and wastewater is now treated before entering coastal waters (EC, 1991). The main exceptions to this are Combined Sewer Overflows (CSOs). When wastewater systems fill up in event of prolonged rainfall the CSO opens and releases the wastewater into the receiving water (Metcalf and Eddy, 2002). Septic tanks can also overflow in cases of extreme rainfall.

With point sources pollutants restricted through regulation, diffuse pollution has now become the major source of bathing water failure in Scotland (Kay et al., 2003; Vinten et al., 2008). This presents a significant challenge to competent authorities enforcing Article 6, who have to identify and quantify all sources of pollution affecting bathing waters (EC, 2002).

This is further compounded by the fact that the various pollutants affecting bathing waters come from sources that are regulated under different regimes or not regulated at all. This information is consequently held by various stakeholders, including SEPA, Wastewater Companies and Local Authorities. The only way to gain a complete understanding is for local stakeholders to work together in a co-ordinated manner. Finding a solution to this is

the central plank for successful Bathing Water Profiles as without knowing where and what the pollutants are, effective methods cannot be developed to monitor them. Chapter 5 gives details of a research study carried out that addresses this issue in more detail (Staines et al., 2003).

This means that any bioindicator(s) chosen to monitor bathing waters needs to be able to detect the impact of multiple pollutants, both point source and diffuse, and give an idea of the ecological quality status of the water body, which can be defined in a quantitative and qualitative manner. Adding this parameter to the requirement of a method suitable for monitoring sub-acute toxicity over a maximum of 28 days helps to narrow down the available methods of biomonitoring of bathing waters.

Organisms subjected to environmental stressors such as pollution or increased temperatures are affected at various levels of biological organisation. This occurs at three distinct, escalating levels of biological organisation;

- biochemical, when initial effects such as enzymes are inhibited or stress hormones are released;
- physical responses such as cellular membrane degradation or development of carcinomas;
- whole body such as growth and reproduction, before eventually leading to mortality if the stress continued.

(McCarty and Nunkittrick, 1996)

Consideration of biological organisation is important in method selection. At each level of biological organisation, indicators of stress can be measured using bioindicator methodologies such as neutral red retention (Lowe et al., 1995), imposex (Axiak et al., 2003) and respiration (Sukhotin et al., 2003). Figure 7 shows that whilst lower levels of biological organisation give rapid, quantitative data they do not demonstrate the ecological relevance of higher levels of biological organisation such as growth, which then aid in understanding the overall community effects of environmental stressors.

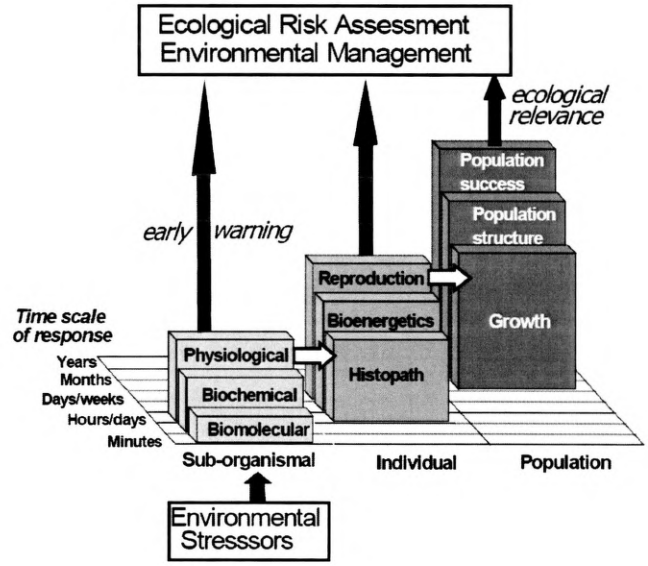

Figure 7 - Levels of biological organisation and their relation to ecological relevance (Adams and Greeley, 2000)

Using low level indicators in isolation would not allow an effective understanding of how the overall ecological status of the water was affected. This would then not enable the BWP to fully realise how pollutants are affecting the bathing waters. This would be similar to reverting to a pass/fail system, which the Directive is trying to move away from (EC, 2002). If looking at this inversely, using only higher levels of biological organisation, whilst more relevant ecologically would not fit within a regulatory framework due to time constraints. The answer is to use both.

As ecotoxicology has progressed from single chemical dose-response experiments researchers have been addressing how to cope with the complexity of whole ecosystems and have strived to progress analyses and approaches in response (Burton, 1999). Chapman likens using low level biomarkers in isolation to the advances in chemical analyses which show that a pollutant is present, but do not relate it to the overall ecological relevance (Chapman, 1995).

In the last 10 years research has moved towards multiple biomarker approaches, with researchers realising this gives a better overview of the holistic water quality (Astley et al., 1999; Brown et al., 2004; Hannam et al., 2009). By combining multiple biomarkers at different levels of biological organisation, it is possible to generate a picture of overall organism degradation which can then be more confidently scaled up to ecological relevance (Galloway et al., 2004a).

This approach gives a holistic overview of water quality, but will not directly point to sources of pollution present within bathing water. To aid in Bathing Water Profiles, competent authorities will need to work closely with other stakeholders to identify where the sources of pollution may be coming from and show the need for a co-operative approach. Chapter 5, Section 2.3 provides details of how this was achieved for this research.

In 30 years water quality assessment has moved from single chemical *in vitro* assessments to multi-biomarker responses that aim to give an overview of the water body. Single chemical analyses will always have an important function in establishing baselines and for regulating point source discharges where possible, but there is now a need to define water bodies in terms of overall risk and their risk management (EC, 2002). Bathing waters are subject to a range of natural and anthropogenic factors that can affect their quality and suitability to bathe in. Researchers are now moving towards Whole Effluent Toxicity (WET) which goes to the next logical step and assumes that effluents and receiving waterbodies are complex mixtures that cannot be easily characterised by individual chemicals due to their potential additive and reductive effects. An example of this is the over estimation of metal toxicity to receiving waters (Sarakinos, 2003). This further advances the idea of ecological relevance over chemical parameters alone.

3.2.3 How to Deploy the Chosen Methods to the Bathing Water?

The first decision on how to deploy a bioindication system is what organisms to use. For a species to be an effective bioindicator it needs to work both *in situ* as well as *in vitro* as data collected in the field have many variables that cannot be created in the laboratory and correlation is needed (Chapman, 2002, Calow, 1993).

The following list shows typical factors that are important to think about when deciding on particular species to be used in marine ecotoxicology studies:

- An important ecological group (based on taxonomy, trophic level or niche);
- Dominant or keystone species (ideally for area being assessed); Identified by community-based studies;
- Widely available (less effort), reasonably available (more effort);
- Easily cultivated in laboratory and genetically stable;
- Can be reasonably collected from laboratory or collected from field;
- Physiology, genetics, taxonomy, behaviour, etc., well known;
- Can be tested with other species/taxa;
- Endpoints ecologically and toxicologically relevant;
- Consistent, measurable response to toxicants can be tested in laboratory or field;
- Sessile – therefore more useful to monitoring contamination in a certain area;
- Resistant to disease and physical damage, can be handled in laboratory.

(Chapman, 2002).

This extensive list would present a daunting challenge to most researchers if lamellibranchia did not exist, i.e. the bivalves molluscs. The most common and understood of these bivalves is *Mytilus*.

The *Mytilus* genus can be found all over the world from both poles to the equator in temperatures from 4C° in the Antarctic to 25 C° in the tropics and various salinities and niches. *Mytilus edulis* (Common or Blue Mussel) is widespread in the temperate northern hemisphere and the most southern parts of South America. Other species like *M. galloprovincialis* (Mediterranean Mussel) are abundant in the Mediterranean and are also found in the U.S., South Africa, Eastern Asia (China, Japan), Australia, and New Zealand (Gosling 1992).

Mytilus edulis has been used extensively in toxicological studies and is one of the most studied organisms in the natural world. From previous work (Staines, 2001) there was knowledge of large stabile communities of mussels present in St.Andrews, Fife. These mussels are easy to access, in clean water (SEPA, 2003) and are in large enough numbers for repeated harvesting for research needs.

There are two ways to use bioindication systems *in situ,* Passive Biomonitoring (PBM) and Active Biomonitoring (ABM). (PBM) is the use of organisms indigenous to the location and ABM involves the transplantation of organisms in containers to locations to be tested (Bruns et al., 1997).

ABM has been extensively used in environmental toxicology, both in terrestrial (Fernandez et al., 2004) and aquatic research (Bodin et al., 2004) and is shown to give better results than PBM due to fact that organisms already present in-situ may have adapted to the pollutants and also enables comparison between ABM individuals and indigenous populations (Smolders et al., 2003).

3.2.4 Summary of Literature

The literature has shown that as third wave water law has progressed within Europe that simple analysis of physico-chemical parameters is not enough to justify the water quality in a holistic manner. Bioindicators have also moved from simple dose-response relationships to integrate multiple biomarkers that attempt to quantify ecological risk in all its complexity. The literature has shown that bioindicator methods offer a valid approach when assessing bathing waters for pollutants and their effects. The literature review has enabled the research to focus on methods that could be effective in assessing bathing waters for pollutants and the next section goes into detail about how they were selected.

3.3 MULTI-CRITERIA ANALYSIS OF METHODS

The literature review highlighted 28 distinct biomarkers which were put into a database for a two-stage multi-criteria analysis (MCA). The MCA overall consisted of a 7-parameter decision-making tool, each biomarker being assessed against each parameter and a score of 1, 2 or 3 was assigned for each parameter. 1 was defined as a poor match to the parameter, 2 was defined as a useful match and 3 defined as a good match to the parameter. The first stage of the MCA consisted of using the 5 Rs of Ecotoxicology originally developed, as 3 Rs by Calow (1992) and extended to 5 by Hopkin (Hopkin, 1993). The 5 Rs are:

- **relevance** - Ecologically realistic, divergence from normal effects;
- **reproducibility** - Same test substance produces same result, standardised, following defined protocol, need several papers (?) good laboratory practice, scientifically and legally credible;
- **reliability** - Able to carry out on demand, setting up tests at will, culture organisms of known quality with ease;
- **robustness** - Anything too demanding in terms of skill and interpretation should be avoided, trained personnel needed;
- **repeatability/ sensitivity** - Sensitive to toxicants, statistically credible distinctions, in particular respect to controls.

These parameters are essential to biomarker research. In an ideal experiment it would be possible to satisfy all of these, however there is often a trade-off between each of them and their suitability depends on what the research is seeking to answer. In this particular research the aim is to identify biomarkers that can be used in a regulatory framework and to this end, once each method was assessed using scientifically rigorous factors, it was also tested against the expense and time taken.

This second stage narrowed down the available biomarkers. Some biomarkers that appeared suitable based on their scientific basis alone were found to take too much time or expense to justify in a regulatory framework. All of the parameters were equally weighted as it was decided that the two stage approach would enable effective prioritisation of methods. The full results of the MCA with assigned scores can be found in Table 7. The seven methods chosen for initial testing are highlighted in yellow.

Table 7 - Multi Criteria Analysis (MCA) of biomarker methods from literature review

Method/ Biomarker	Relevance	Robustness	Reproducibility	Reliability	Repeatability	Expense	Time	Total
Acetylcholinesterase (AChE) inhibition	3	3	3	3	2	2	2	18
Anoxic survival time	2	3	3	3	2	3	1	17
Apoptosis	1	2	1	2	3	1	3	13
Respiration	3	3	3	3	3	1	3	19
Carboxylesterases (CbEs)	2	2	3	3	2	2	2	16
Cellular Energy Allocation	2	3	2	3	2	3	3	18
Comet Assay	1	3	3	3	3	1	3	17
Cytochrome P450	1	1	2	2	2	1	1	10
DNA adducts - Genotoxic indicator	1	1	3	2	3	1	2	13
DNA Strand Sission Factor	1	1	2	1	2	1	1	9
Endocrine Disruption	3	2	3	2	2	1	1	14
Glutathione transferases (GSTs)	3	2	3	3	2	1	3	17
Growth	2	3	3	3	3	3	3	20
Immunoperoxidase Staining	1	2	1	2	2	2	2	12
Imposex	3	2	3	3	3	1	1	16
Larval development, growth and mortality	3	3	3	1	2	3	2	17
Malonedialdehyde (MDA),	3	2	3	3	3	2	1	17
Metallothionein induction	2	3	3	3	2	2	2	17
MicroNucleus formation (MN)	2	3	3	3	3	3	2	19
Multichemical Resistance (MXR)	2	3	2	3	3	2	2	17
Neutral Red Retention Assay	3	3	3	3	3	3	3	21
Nitric Oxide Synthase	1	2	1	2	2	1	1	10
Peroxisome Induction	3	3	2	2	3	2	2	17
Phagocytosis	1	1	3	2	2	1	1	11
RNA/DNA Ratio	2	3	3	3	3	2	3	19
Scope for Growth (SFG)	3	2	3	3	3	1	1	16
Total Oxidant Scavenging Capacity (TOSC)	3	2	3	3	3	1	2	17

3.3.1 Analysis of MCA

Table 7 shows that the 7 lowest scoring methods were also scored at 1 for ecological relevance. It can be seen that several of these methods are at the lowest level of biological organisation, genotoxic effects. The biomarkers chosen for the Framework need to monitor for pollutants and give an overall picture of ecological quality. The low scoring methods, whilst giving rapid data, do not allow for correlation with ecological quality, such as growth does.

The top scoring 7 methods also score at 2 or above for ecological relevance and this can be seen in the level of biological organisation that they are focussed on. Growth is at the highest level of biological organisation by focussing on the overall organism's reactions to stress. Other methods in this group do focus on lower levels of biological organisation but are extremely relevant to the overall organism, such as Acetylcholinesterase Inhibition (AChE) which assesses levels of acetylcholinesterase (AChE) enzyme that breaks down acetylcholine. Acetylcholine is the principal neurotransmitter found in the sensory and neuromuscular systems in most species. If Acetylcholine builds up it causes a continuous and excessive stimulation of the nerve and muscle fibres, which leads to tetany, paralysis and eventual death.

The two-stage analysis allowed all the methods to be checked against regulatory requirements and all but one of the highest scoring methods scored above two for expense and time.

3.4 PILOT STUDY OF SELECTED METHODS

3.4.1 Introduction

In the summer of 2004 a pilot study of biological monitoring was carried out on the Angus coastline to assess the methods and techniques highlighted by the literature review and Multi Criteria Analysis. This was to develop rigorous protocols and approaches before the final BWMF testing in 2005. It should be noted that at the same time as the pilot, a joint research project with SEPA was run to assess the catchment characteristics of nearby watercourses (SEPA, 2004a). This helped to fulfil the requirements of Bathing Water Profiles (BWP) and related Water Framework Directive articles pertaining to the identification of pollutants affecting water bodies. For more information on this, see Chapter 5. Figure 33 in Appendix 1 shows all locations referred to in this thesis.

The pilot of 2004 was aimed at testing a number of research goals, these being:

- assessing active biomonitoring cage design, fabrication and placement *in situ;*
- assessing selected biomonitoring methods using both *in situ* and *in vitro* verification;
- assessing the effectiveness of the selected biomonitoring methods within a regulatory framework.

3.4.2 Assessing Active Biomonitoring Cage Design, Fabrication and Placement *in Situ*

In the pilot study, work was carried out by the researcher in conjunction with an MSc student (Pazos-Roiz, 2004) and used Active Biomonitoring Methods (ABM) described in Salazar and Salazar (2000). This reference provides detailed practical advice on the materials, designs and fabrication of various types of cages for monitoring and is often cited by other researchers (Wedderburn, 2000; Steinert, 1998; Smolders, 2004). From the cage designs available, the most suitable was a semi-rigid compartmentalised cage. This enhances water-flow around the mussels, enhancing the availability of pollutants in the water column. Also by utilising a flexible frame this provides protection in open water. Specific details of all aspects of cage construction can be found in Section 3.5.

3.4.3 Location Specifications

Locations for ABM deployment were chosen in co-ordination with joint SEPA study (SEPA, 2004a). This allowed a holistic overview of the waterbodies, showing anthropogenic and ecological pollution inputs into the catchment and the resulting effect on the receiving waterbody, i.e. the bathing water containing the deployed active biomonitoring cage.

Cages were placed at Arbroath and Carnoustie at the point where the monitored rivers fed into the bathing waters. This enabled the best opportunity for correlation between the two studies when a pollution event may occur. The Grid References for the cages were (NO630399) for Arbroath and (NO574346 and NO564340) for Carnoustie. With point-source discharges increasingly controlled through key second-wave directives (EC, 2002a), diffuse pollution has become the prominent issue within European bathing waters and this entrainment happens primarily through rivers and their tributaries.

3.4.4 Results

Open water testing of the cages was carried out in August of 2004. The cages were held in place using high-density polypropylene rope which tied to ironwork at Carnoustie. The cages in Arbroath were heavily weighed down as there were no available fixing points. Mussels were well spread throughout the cage and extra mesh was placed around the cages to exclude littoral predators such as crabs and dog-whelks. The cages were then deployed by two-man teams into the designated locations.

After only 7 days of initial ABM testing, however, the cages had been vandalised, being completely destroyed, with the frames broken and the nets slashed which led to a loss of valuable research time and data. This issue was a recurring theme of anecdotal evidence by other local researchers (O'Keefe, 2004) and in some papers (Salazar and Salazar, 2000). The cages described in Salazar and Salazar are well designed for the purpose, however they are highly visible and as such open to attacks as happened in this research.

3.4.5 Conclusions

This aspect of the pilot study proved invaluable as it meant that there was sufficient time to reconfigure ABM cage design before the live test of the framework in the summer of 2005, No further pilot tests were carried out. Planned *in situ* work for the summer had to be

suspended with only *in vitro* work carried out to assess the methods. Section 3.6 provides information on the new cage designs implemented as a result of this pilot.

3.5 ASSESSMENT OF SELECTED BIOMONITORING METHODS USING IN VITRO VERIFICATION

Of the seven methods chosen through the Multi-Criteria Analysis (MCA), three were chosen to be tested during the pilot study period, these being Respiration, Acetylcholinesterase Inhibition (AChE) and Micronucleus Formation.

These methods were chosen for the pilot for a number of reasons:

The three chosen methods occupy three different levels of biological organisation from Micronucleus (genetic) through to Acetylcholinesterase (AChE) (chemical) and finally up to Respiration (physiological);

Of the remaining four other methods highlighted in the MCA (Section 3.3):

- Growth is a basic scientific measure of allometric indices and is relatively inexpensive in time and money;
- Cellular Energy Allocation (CEA) is a relatively new method and detailed protocols were not available at the start of the pilot;
- There was an issue over equipment allocation with regard the DNA/RNA ratio and also there was ongoing discussion of the similarity of data yield from this and CEA.

The researcher had existing analytical knowledge of the Neutral Red Retention assay (NRR) through previous research (Staines, 2001).

3.5.1 Methods

The following section only provides a brief summary of the methods used; full details are given in Section 3.6. The pilot study used standardised methods as described in the literature; respiration rate by Camus (2002) was used. Changes in respiratory rates are a well known indicator of stress (Sukhotin, 2003; Honkoop, 2003; Giordani et al., 2009). It is fairly rapid and easy to monitor, which is an attribute essential for use within the framework and within regulation overall (Smolders, 2003).

To summarise the respiration method, five mussels were selected at random using a random number generator and assigned numbers. The organisms were placed into five separate respirometry chambers, which were sealed and incubated for 4 hours. Further to this five empty respirometer chambers, containing seawater only were also sealed for 4 hours to use as a contrast. After 4 hours the oxygen concentration in each chamber was measured using a Hach HQ20 Portable LDO Dissolved Oxygen Meter which was calibrated to seawater, 37 parts per thousand of salinity. The result was then divided by four to give an hourly respiration rate and finally normalised against mussel tissue dry weight to give a result of mg O_2 per gram dry weight per hour.

Acetylcholine is the principal neurotransmitter in the sensory and neuromuscular systems in most species. The activity of this system is vital to the normal behaviour and muscular function of organisms. Certain toxicants can exert a detrimental effect by inhibiting the acetylcholinesterase (AChE) enzyme that breaks down acetylcholine. This results in a build up of acetylcholine which causes a continuous and excessive stimulation of the nerve and muscle fibres, which leads to tetany, paralysis and eventual death. The level of AChE detected therefore can be used as a biomarker of stress in organisms. The method used in the pilot was developed by Ellman (Ellman, 1961) and measures the increase in absorbance of the sample at 412 nm in the presence of 0.075M acetylthiocholine as a substrate and 0.1 mM 5, 5-dithiobis-2-dinitrobenzoate (DNBT). The enzymatic reaction rate was quantified against a blank without substrate for each activity measurement. AChE activity is expressed as nmols of product developed per minute per mg of protein. Protein was measured spectrophotemetrically using the Coomassie dye protein assay kit.

The Micronucleus assay was first developed to identify structural chromosome damage induced by chemicals and has principally been used as a method to assess the genotoxic effects induced by cumulative exposure to environmental chemicals in aquatic fauna. Micronuclei are small cytoplasmic nuclei formed at the end of cell division by chromosomes or their fragments and provide confirmation of clastogenic or aneugenic damage. Figure 8 shows various micronuclei images highlighted by arrows, taken from Dailianis et al., (2003).

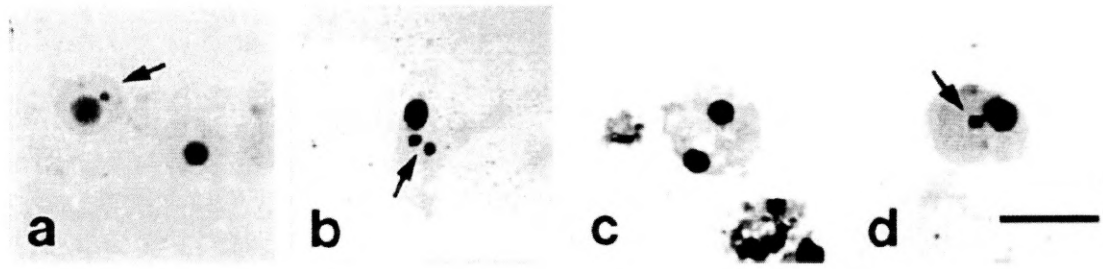

Figure 8 - Examples of Micronuclei (Dailianis et al., 2003)

To critically assess genotoxic damage, 2000 intact cells were viewed under a microscope and the frequency of micronuclei was converted to a score using Tate's method (Tates et al., 1980).

The three methods were tested *in vitro* using standard methods, with pollutants that could commonly be found in Bathing Waters; Copper, Pesticides and Wastewater (Matthiessen, 2002).

Copper

Copper has been used in marine paints to prevent fouling of ship keels by organisms such as barnacles and seaweed since the early 18th Century as this can severely reduce movement through water and lead to a decrease in fuel efficiency (Valkirs, 2003). Copper is a well-defined pervasive pollutant that has a well understood mode of toxicity, with evidence of cellular membrane disruption and neurotoxic damage common (Brown, 2004).

Pesticides

Diffuse pollution is the key driver in bathing water failure and pesticides are a useful indicator of this as they are contained within run-off from agricultural sources upstream (Lionetto, 2003). The pesticide that was chosen was Diuron (Sigma, Poole). Diuron which is the chemical name for N-(3, 4-dichlorophenyl)-N,N-dimethylurea ($C_9H_{10}C_{l2}N_2O$) is a widely used herbicide. Diuron is highly mobile through runoff and is a persistent chemical within the aqueous environment. Diuron is toxic to fish and aquatic invertebrates and as such is useful when testing water quality with invertebrates such as mussels that were used within this research.

Wastewater

The final contaminant chosen was wastewater, which contains a complex mixture of pollutants including pathogens, biodegradable organics and nutrients which can affect bathing water quality and associated human health (Metcalf and Eddy, 2002). This is a complex mixture which is constantly changing and as such monitoring individual components is not feasible. By measuring overall toxicity within a suite of biomarkers such as in this research, the real effect of wastewater can be measured (Manusadzianas, 2003). The wastewater was collected from a pumping station in Dundee (Grid Reference NO377295).

Mussels were placed in testing tanks with the concentrations of pollutants as shown in Table 8 and tested over 6 days for signs of organismal stress. Each pollutant was tested in separate tanks. During this time the test organisms were fed everyday and kept in dark, quiet conditions to minimise stress that could affect the results.

Table 8 - Pollutant concentrations for testing

Pollutant	**Pollutant concentration in tank**				
Copper	0 µg/l	50 µg/l	100 µg/l	150 µg/l	200 µg/l
Pesticide	0 µg/l	13 µg/l	100 µg/l	1000 µg/l	
Wastewater	0 µg/l	50 µg/l	100 µg/l	150 µg/l	200 µg/l

3.5.2 Results

Micronucleus Assay

At an early stage in the testing it was realised that the micronucleus assay, whilst relatively easy to measure, was extremely time consuming, an issue not mentioned in the sourced paper, e.g. Siu (2004). Relative to the methods, preparation time and type of analysis (light microscopy) is straightforward. For a regulatory regime the assay proved to be far too time consuming and was not suitable for the use in the BWMF. This shows how important a pilot study is. Whereas on paper the method appeared to be well suited to use within the BWMF, practical application showed that it was not. As such this method was removed from the research considerations at this stage.

Acetylcholinesterase inhibition (AChE) Assay

The first pollutant tested with the AChE assay was copper. Table 9 shows the AChE activity (µmol/min/mg protein) for each concentration of copper over the 6 day assay period, with Figure 9 showing a bar chart of these results.

Table 9 - AChE activity for each concentration of copper over the 6 day assay period

Concentration µg/l	**Day**					
	1	2	3	4	5	6
0	15.83	10.71	15.77	7.85	27.87	3.184
50	14.83	6.63	5.89	11.41	9.98	8.254
100	12.76	10.96	7.41	12.76	9.46	9.83
150	10.24	12.88	19.51	12.73	19.7	3.86
200	19.74	4.69	6.8	7.74	25.49	2.84

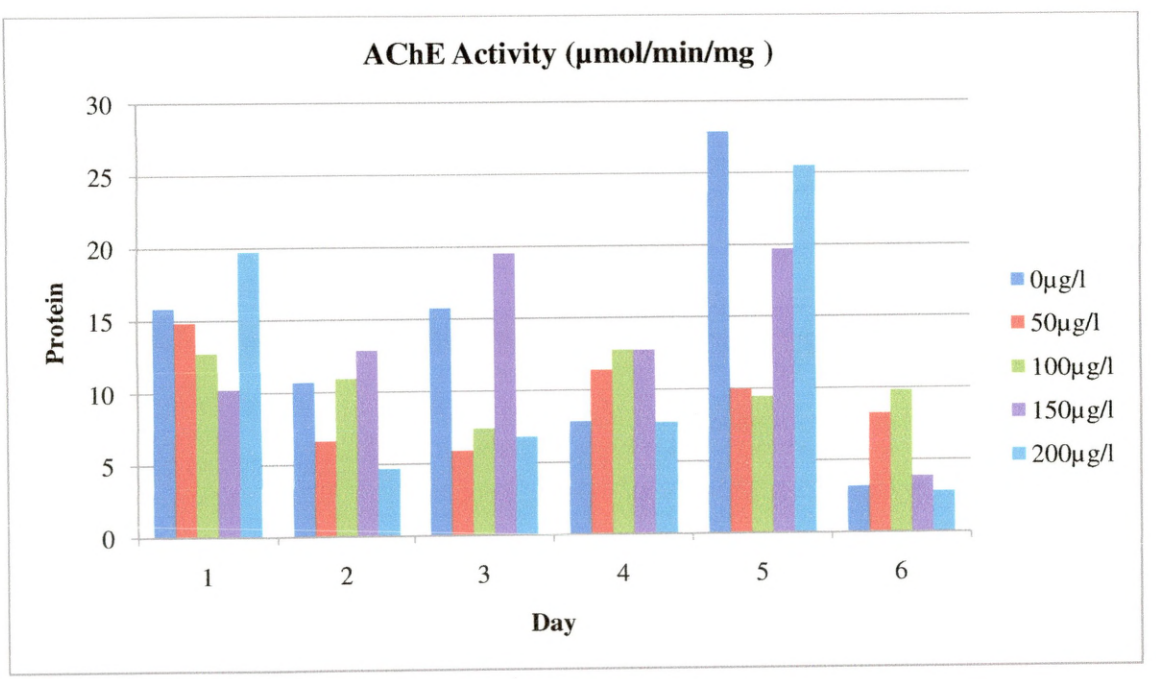

Figure 9 - Graph showing AChE activity according to copper concentration over 6 days

From Figure 9 it can be seen that there is no clear relationship between copper concentration and a change in AChE activity over the 6 day assay period. This could show that there may be a lack of sensitivity of the assay, which may affect its potential use within the BWMF. This may also mean that the concentration of copper is not sufficient to affect AChE activity. If sensitivity to copper was apparent then a decrease in AChE would be expected and be increasingly suppressed with increased pollutant concentration. This is not shown by looking at Figure 9 and no clear pattern emerges.

Table 10 and Figure 10 show the effect of pesticide (Diuron) on AChE activity, which is a key pollutant that affects marine invertebrates.

Table 10 - AChE activity for each concentration of pesticide over the 6 day assay period

Concentration µg/l	**Time (hours)**		
	48	96	144
0	38.14	19.61	10.16
13	21.365	9.20	10.66
100	11.75	5.33	5.52
1000	9.89	11.95	7.17

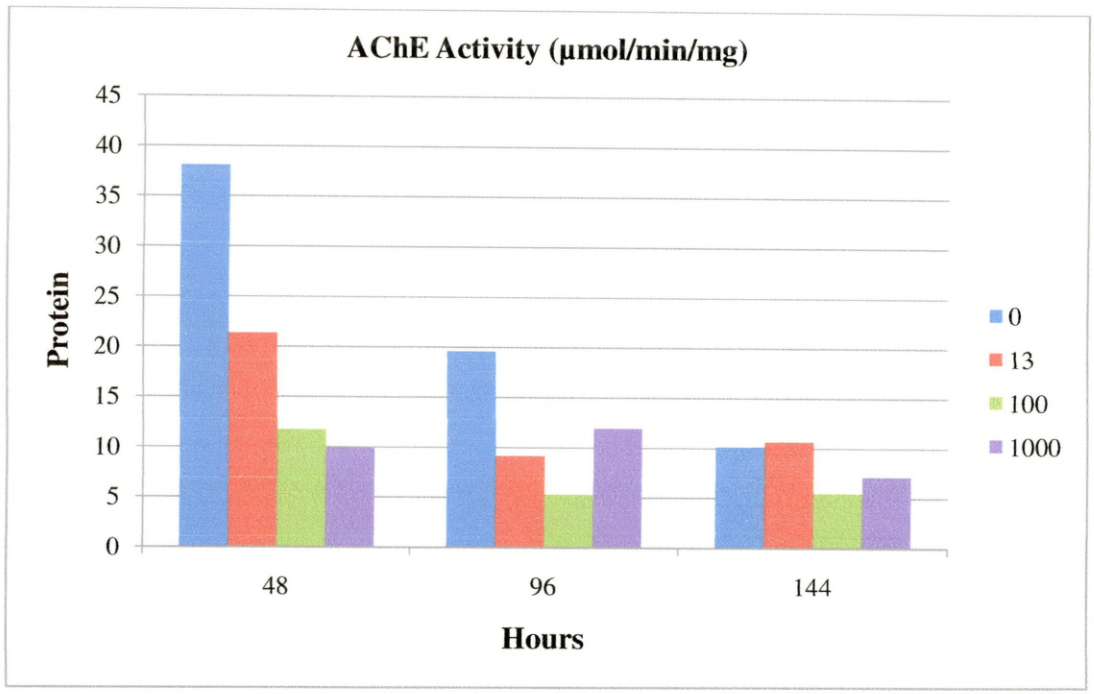

Figure 10 - Graph showing AChE activity according to pesticide concentration over 6 days

From Figure 10 it can be seen that AChE is decreasing over the 6 day assay period over all concentrations; this includes the control. The control should not be changing which shows that there may be other parameters affecting the testing. However, when compared to the other tanks which had received pollutant dosing, the pattern of AChE activity is markedly different with all concentrations showing various patterns of AChE activity. This once again could show the lack of sensitivity of the assay.

The final pollutant to be tested with the AChE assay was wastewater which is a complex mixture which is made up of many constituents including pathogens, organic compounds and nutrients. Table 11 shows the AChE activity (µmol/min/mg protein) for each concentration of wastewater over the 6 day assay period, with Figure 11 showing a graph of these results.

Table 11 - AChE activity for each concentration of wastewater over the 6 day assay period

Concentration µg/l	Time (hours)		
	48	96	144
0	8.46	14.37	22.63
10	10.61	11.09	10.85
50	9.65	7.13	13.07
100	10.77	13.01	13.35
200	7.76	36.72	16.24

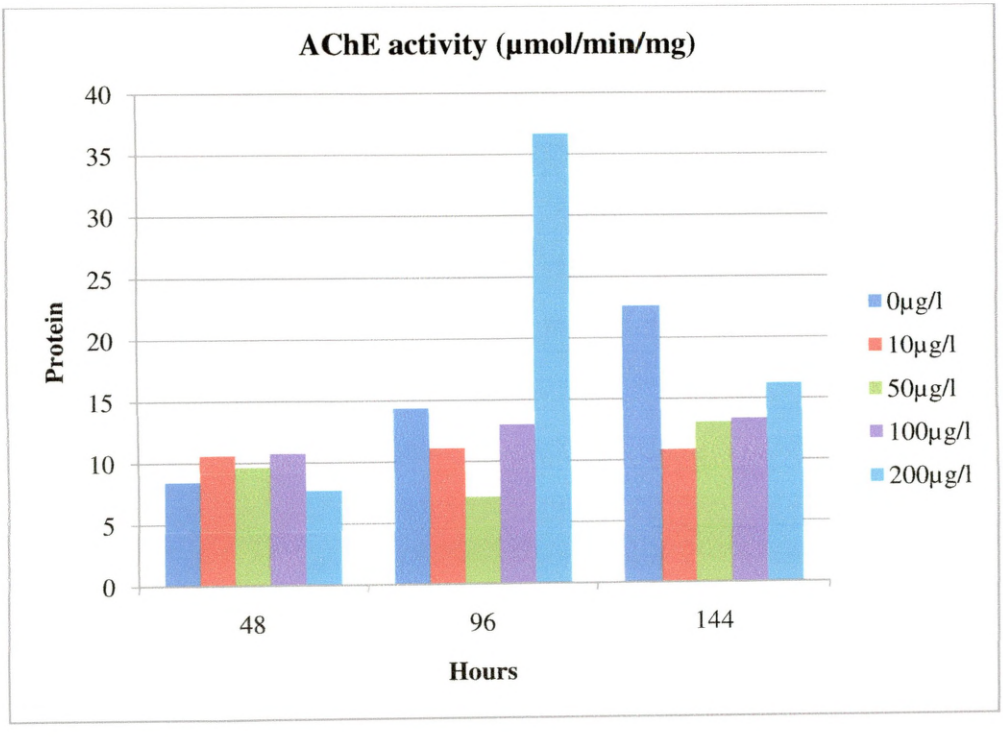

Figure 11 - AChE activity for each concentration of wastewater over the 6 day assay period

Once again the data from the wastewater show that that assay may be insensitive to the pollutant, which makes the case for removing the assay from the studies even more apparent. When looking at other papers, such as Brown (2004), there are issues with the standardisation of the AChE assay and Mora (1999) states that mussels are less sensitive to pesticides than other invertebrates such as nematodes and insects. The AChE assay reacted totally differently with each pollutant and with each concentration, which represents a lack of sensitivity or repeatability which is defined by Hopkin (1993) as; 'Sensitive to toxicants, statistically credible distinctions, in particular respect to controls'.

The causes of this may have become clearer with further extensive trials; however this does raise an issue for use within a regulatory framework and how reliable it may be. As such it was decided to remove the assay from the overall 'suite' of biomarkers to be deployed in the 'live' testing of the BWMF in the summer of 2005.

Respiration

Respiration was tested with copper only and the results can be seen in Table 12, and in graphic form in Figure 12. Respiration was recorded as mg O_2 per dry mass/per hour.

Table 12 - Respiration for each concentration of copper over the 6 day assay period

Concentration µg/l	Day					
	1	2	3	4	5	6
0	0.86	0.80	1.10	1.11	0.61	1.15
50	0.13	0.66	0.71	0.66	1.13	1.29
100	0.16	0.83	0.39	0.78	0.77	1.22
150	0.18	0.81	1.35	0.93	0.78	2.70
200	1.12	1.09	0.89	1.06	0.67	0.438

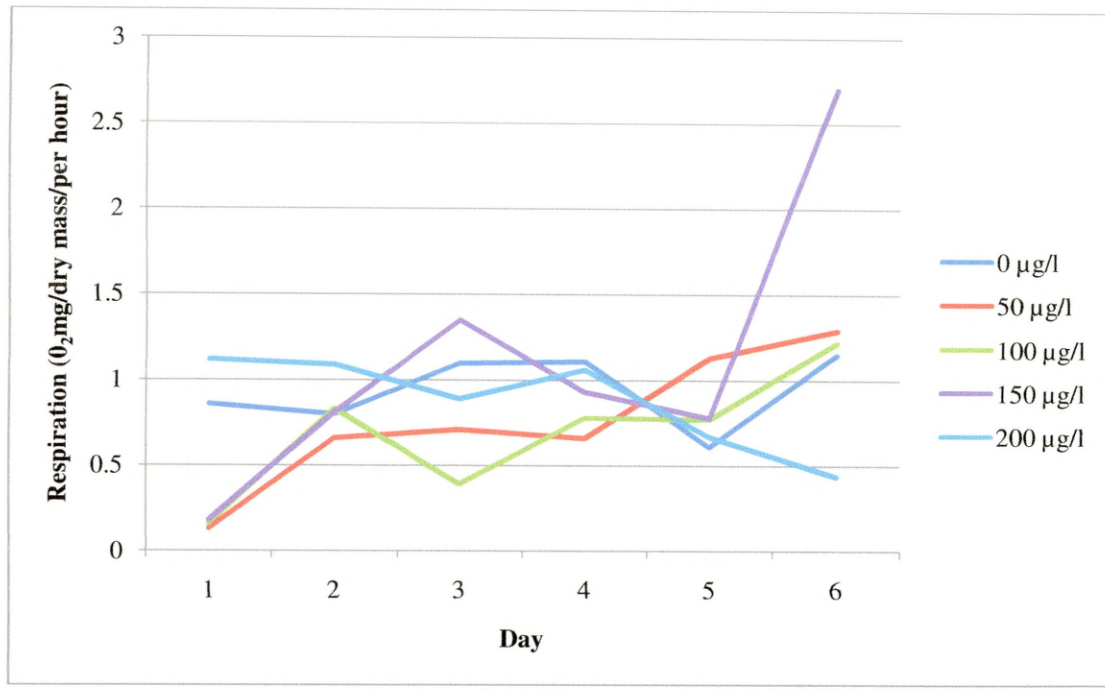

Figure 12 - Respiration for each concentration of copper over the 6 day assay period

From Figure 12 it can be seen that there is a mixed message from the data. When looking at the copper concentration over 200 µg/l, it can be seen that there is a definite reduction in the respiration rate of the test organisms that warrants further investigation in the research. As such, whilst tests were inconclusive, it was decided that respiration should be used in the research and investigated more fully.

3.5.3 CONCLUSIONS

From the results it can be seen that the decision to pilot the limited selection of biomarkers was well made.

The Micronucleus assay was, on paper was a promising useful and cheap genotoxic biomarker. In practice it was time-consuming and not suitable for a regulatory regime. The assay, however, would be useful in other types of biomonitoring over longer time periods and was only disregarded due to the requirements of the research.

Comparatively, the AChE assay was disappointing in its delivery, where many papers had suggested it as a useful biomarker (Minutoli, 2002), others had also had issues with the standardisation and sensitivity of the assay, as discussed previously.

Finally the respiration assay which is cheap and easy to use, also gave some erratic data. There were issues with the equipment at this stage and so it was decided that this assay should be kept within the research and thoroughly tested. It was decided to use this in the final suite of methods in the 'live' trial.

If this research was only on biomarkers then the above assays may prove to be worthwhile, however in trying to develop an interdisciplinary framework in a limited timescale, it proved difficult to fully realise each assay.

In keeping with the interdisciplinary philosophy of the thesis a thorough evaluation of methods was carried out, but this proved to be inconclusive in selecting methods. In a monodisciplinary study time would and could be spent at the pilot stage before any field testing. In this research there is a trade off between depth and breadth

The next section provides expanded details on each method and the ABM deployment.

3.6 BIOLOGICAL MONITORING METHODS

The methods detailed are therefore; neutral red retention, respiration and growth. Further to these specific biomarkers, background environmental measurements were also taken and methods are discussed at the end of this chapter.

From the original seven methods that were short listed from the MCA process, the following decisions were made:

Micronucleus - was removed due to the long assessment time;

AChE - was removed due to the insensitivity as shown in the pilot;

Respiration – was kept and put forward to testing in the 'live' trial;

Growth – was kept and put forward to testing in the 'live' trial;

Cellular Energy Allocation – was removed due to time constraints;

DNA/RNA ratio – was removed due to the equipment not being available;

Neutral Red Retention assay - was kept and put forward to testing in the 'live' trial.

3.6.1 Neutral Red Retention Assay

The method was carried out in accordance with Lowe (1995), with 'Molluscan Physiological Saline Solution' (MPSS) as formulated in Brown (2004). The method is described with any changes made by the researcher noted.

Mussel valves were prised apart with care using a broad-backed solid scalpel which was held in place whilst 0.5 ml of haemolymph was withdrawn from the anterior adductor muscle into a 2.5 ml hypodermic syringe fitted with a 25 gauge needle, containing 0.5 ml of MPSS. In order to reduce shearing forces the needle was then removed and the contents of the syringe dispensed into a 2ml Eppendorf tube. This was then held on ice until needed.

A 50µL aliquot of the cell suspension was dispensed onto a 76 x 26 mm microscope slide and suspended on a rack above a water ice mixture (incubation temperature ~10°C) for 15 min in a lightproof humidity chamber to allow the cells to attach. Excess solution was then carefully tipped off, 40 µL of the neutral red working solution was added and an 18 x 18 mm cover slip applied.

The preparations were removed and inspected under a microscope (total magnification x 625). Following a further 15 min incubation the preparations were examined again and subsequently at 30 min intervals to verify at what point in time there was indication of dye loss from the lysosomes to the cytosol.

The test for each replicate was completed when dye loss was evident in 50% (numerically assessed within each field of view) of the small granular haemocytes and the time recorded. The mean retention time was then calculated from five replicates.

3.6.2 Respiration

The method was carried out in accordance with Camus (2003).

For each sampling station five randomly selected mussels were collected and placed into separate respirometer chambers, which were sealed and incubated for 4 hours at 8C in lightproof conditions. To achieve this, the researcher placed the respirometer chambers in a laboratory fridge set to the designated temperature. Five empty respirometer chambers, containing seawater but no bivalves, were also incubated as controls for 4 hours at 8C in lightproof conditions.

After 4 hours the oxygen concentration in each chamber was measured using the Oxygen Probe, which was calibrated to seawater, typically 37 parts per thousand salinity. The result was then divided by four to give an hourly respiration rate and finally normalised to mussel tissue dry weight to give a result of mg O_2 per gram dry weight per hour.

3.6.3 Allometric Indices (Growth)

The method was carried out in accordance with Soto (2000).

The shell length of mussels from each sampling station was recorded using callipers. Whole mussel tissue was then dissected using a broad-backed solid scalpel and weighed in grams to two decimal places; this gives the wet weight of the mussel tissue (WW). Mussel tissue was then placed in a general-purpose laboratory oven and dried at 105C constant temperature for 24 hours to give the dry weight of mussel tissue (DW). Wet weight is then divided by dry weight to give a ratio, which can indicate health of the organism, the mean dry weight, wet weight and ratio was calculated from five replicates. In 2004 baseline standards were established (*n=60*), giving an average ratio of 8.05 $R^2 = 0.75$.

3.6.4 Active Biomonitoring

Active biomonitoring was carried out during August–October 2005 using methods and guidance found in Salazar and Salazar (2000), with modifications from personal experience noted in the pilot study. The apparatus and methods are detailed because Salazar and Salazar provide general guidance but do not give specific designs for depuration and holding tanks.

3.6.4.1 Apparatus

Organism Depuration and Holding Prior to Deployment

Techne C-400 Circulator
Techne M-1000 Flow Cooler
Stainless Steel Cooling Coil
Non-Rigid Tubing Approx 30mm~ Diameter - For use with cooler
Organism Holding Tank + Lid (227 l)
Hagen Elite 802 Air Pump x 2 (output 3000 cc per minute per unit)
10 Metres of Silicone Airline tubing
Airstones x 4
Interpet Liquifry Marine (Invertebrates) 100ml
Insulation Material Polystyrene packing sheets (Approx 40mm thickness)

Active Biomonitoring Deployment

PVC Tubing 4 X 1 metre per cage
High-density polypropylene Mesh ~1mm Mesh Size
Flexible High-density polypropylene Mesh Bags x 12 ~1mm mesh size
Plastic Coated wire for cage compartmentalisation and Line to moor mesh bags/cages to substrate

3.6.4.2 Materials

Anti-Freeze for flow cooler

100-150 litres Seawater

3.6.4.3 Methods

Organism Collection

The Common or Blue Mussel *Mytilus edulis* specimens were collected at St. Andrews East Sands beach where a large stabile homogenous population exists, with relatively easy access at low tides. This population was known about from previous work (Staines, 2001).

Individuals were collected by hand and placed into buckets, with approximately 300 mussels collected for each month of sampling carried out. This number is attained by multiplying the following experimental factors as shown in Table 13.

Table 13 - Experimental factors leading to total mussels needing to be collected per month (28 days)

Experimental Factor	**Number**
Number of Sampling Stations	3
Number of Methods*	3 (*2)
Number of Replicates per Method	5
Number of Days Sampling	8
Total Number of Required Mussels	240
+ 20% in case of unexpected mortality/ loss	300~

* Respiration and Growth methods use same individuals

Larger mussels were selected to increase the amount of haemolymph available for the Neutral Red assay; the average length of mussels collected (*n=60*) was 57mm $\pm$ 4.39mm.

Organism depuration

Collected mussels were carried in aforementioned buckets and transported to a 227 litre organismal holding tank, which was set up thus; before mussels were placed in the tank, approximately 150 litres of seawater (Salinity 37$\pm$1 parts per thousand, Temp 15$\pm$3 C DO 8.5$\pm$0.5 mg/ml) was collected from a known clean area, Kingsbarns, Fife, and oxygenated using two Hagen Elite 802 Air Pumps, with four airlines attached to deliver a total of 6000 cc of air per minute to the water.

Water temperature was regulated to ambient in-situ levels using a closed-circuit cooling system consisting of a Techne C-400 Circulator, which pumped water through to a Techne M-1000 Flow Cooler unit before passing through a stainless steel cooling coil submerged into the Holding tank, to enable effective temperature stability. This was further aided by using polystyrene packing sheets (approx. 40mm thickness) to fully surround the holding tank this increases temperature stability. The tank was held in a dark, isolated room, with the lid of the tank on at all times except feeding due to the photosensitive nature of mussels and stress that can occur due to excessive noise/disturbance (Gosling, 1992). A diagram of the complete organismal holding tank and associated equipment is presented in Figure 13, which was established using guidelines as set out in Adey (1991).

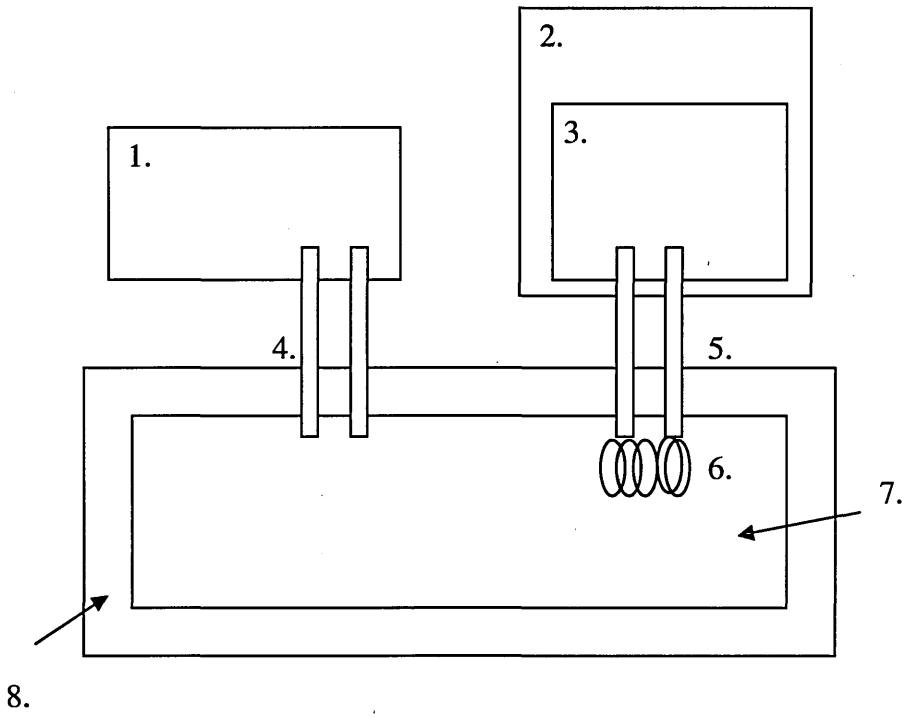

Figure 13 – Diagram of Organismal Holding Tank

1. Hagen Elite 802 Air Pump x 2 (output 3000 cc per minute per unit)
2. Techne M-1000 Flow Cooler
3. Techne C-400 Circulator
4. Non-Rigid Tubing Approx 30mm~ Diameter
5. Silicone Airline tubing
6. Cooling Coil
7. Organism Holding Tank + Lid (227 Litres)
8. Insulation Material

The mussels were held in the holding tank for 48 hours to allow them to depurate, which is vital to establish effective data; this treatment was used for all parts of the study, to maintain accurate data.

Active Biomonitoring (ABM) Deployment

In the pilot study in the summer of 2004, cages for ABM were first fabricated using designs as set out in Salazar & Salazar using semi-rigid PVC-tube frames, with oyster cultch netting containing the mussels suspended within the frame. Added to this original layout was an all-enclosing anti-predator mesh to stop inter-tidal predators such as common crabs (*Cancer pagurus)* and dog whelks (*Nucella lapillus),* which are not present with deeper water testing.

After only 7 days of initial ABM testing during the pilot study, however, the cages had been vandalised which led to a loss of valuable research time and data. A possible option for the ABM was to deploy deep water cages, however in line with the research requirements to make the monitoring fit within a regulatory regime, i.e. cost-efficient and rapid (Wells, 2001) this was decided against. Future cages were designed with the pilot in mind, using non-framed mesh sacks that were compartmentalised using wire and time was spent looking for suitable places that were accessible for research, yet in sites that were not visible to casual observers. These flexible cages were then held in place using available in situ anchors such as rocks and pebbles and tied down using polypropylene rope if needed (Figure 15).

Figure 14 - Modified net design

Organism Sampling

Sampling was carried out in 28-day cycles, with 8 visits over the cycle; twice per week .10 test mussels per location were gathered by hand.

3.6.5 Background Environmental Measurements

As well as carrying out Active Biomonitoring using the aforementioned methods, water quality and other ambient variables were monitored so that at time of interpretation of data there was a better picture of what may be happening. These were then also linked to SEPA monitoring and United Utilities spill data for wastewater assets in the surrounding area.

3.6.5.1 Temperature

Air temperature was recorded from a RAF Leuchars meteorological station, location on Figure 33, and recorded every sampling day. Water temperature was recorded using a HANNA Ruggedised HI-9033 conductivity meter (Leighton Buzzard, UK), all recordings were in degrees Celsius. Temperature is an important factor in organismal metabolism.

3.6.5.2 Conductivity

Conductivity of the water at each sampling station was measured using a HANNA Ruggedised HI-9033 conductivity meter (Leighton Buzzard, UK) and measured in Parts Per Thousand (ppt). This is important to show how change in ionic strength may affect data due to stress on organisms.

3.6.5.3 Ambient Meteorological conditions

Local weather conditions were monitored from the RAF Leuchars meteorological station and recorded every sampling day, also on site observations were made by the researcher, this is useful to assess whether there may have been storm conditions, which increase the chance of wastewater discharge and field run-off diffuse pollution and hence the degradation of bathing waters.

CHAPTER FOUR - REVIEW OF CURRENT COMMUNICATION STRATEGIES AND DEVELOPMENT OF PUBLIC DISSEMINATION PRACTICES AND TOOLS TO SUPPORT COM 581

4.0 PURPOSE OF THIS CHAPTER

In Chapter 2 it was shown that there has been a large increase in the need for communication and information to European citizens, most notably through the Aarhus Declaration (EC, 1998). This has come about through the 'greening' of European policy since the 1960s. It is also shown in the requirements of COM 581. Article 16 in COM 581 describes the specific information that should be available to the public but does not specify how to do this. Once again this shows that using only COM 581 as a base for any development of methods or approaches is not possible without greater understanding of the disciplines covered. This reinforces the need for interdisciplinary research.

The purpose of this chapter is to gain understanding of communications and how best to develop them in relation to the aim of this research. As seen in Chapter 2, currently information on bathing water quality is difficult to find in a short space of time (EPC, 2003). Solving this problem is intrinsic to the development of the Framework and its successful testing, due to the need to relate management measures and water quality measurements required under COM 581 to the public.

4.1 INTRODUCTION

"The two words 'information' and 'communication' are often used interchangeably, but they signify quite different things. Information is giving out; communication is getting through."

(Sydney J. Harris, 1917–1986).

Article 19 of the Universal Declaration of Human Rights gives the right to freedom of opinion and expression, which "includes the freedom to seek, receive and impart information and ideas through any media and regardless of frontiers". Article 27(1) of the same Declaration provides for the "right freely to participate in the cultural life of the community ... and to share in scientific advancement and its benefits" (UN, 1948).

The European Union has made public involvement in environmental decision-making a key aspect of its legislation. In producing the 4th Environmental Action Programme (1987-92), the EU stated that better access to environmental information for the public was a priority area and part of the 1987 programme (EC, 1987). From this 4th EAP, the Freedom of Access to Environmental Information Directive 90/313 was introduced in 1990 which requires public authorities to give access to information relating to the environment to any natural or legal person at his request (EC, 1990). This is covered in more detail in chapter two.

Since the original Bathing Water Directive was launched in 1976, the public has become increasingly aware of their environment and the effects that they can have on it. 65% of Europeans believe that they can make a change to their environment, with 45% of Europeans believing that greater access to information is a key to improving the environment (EU, 2003). In previous attempts to revise the bathing water directives (EC, 1994, 1997a) there were calls for greater public communication. However, these revisions failed on scientific guidelines and it was not until the 1998 UN-ECE Aarhus Convention on Access to Information and Public Participation in Decision Making that a commitment to communication was established (EC, 1998).

Public Communication has moved on greatly from the original Bathing Water Directive, in which there was brief mention of delivering 'objective information' to the public (EC, 1976). COM 581, in contrast, has dedicated no less than 40% of all articles to informing the public, with Articles 15 and 16 dedicated entirely to this issue (EC, 2000).

This chapter discusses the basis of mass communication, which are used to describe communication tools and strategies that operate at a large scale with the aim of 'reaching and involving virtually everyone in society to a greater or lesser degree' (McQuail, 2000). This includes cinema, radio, television and newspapers, which are traditional mass media technologies and 'new media' such as the Internet and text messaging. Also reviewed in this chapter are the various communication models that exist and an assessment is made of their appropriateness to this research. Work on the three components required in a communication strategy (Message, Audience and Channel (Rohrmann, 1992) are presented.

4.2 MASS COMMUNICATION

Mass Communication as an identifiable phenomenon was first recognised in the 1920s with the defined term 'mass communication' ascribed in the late 1930s (Ruddock, 2000). There is still no one agreed definition for the phenomena. Gerbner (1967) provided a concise description of 'social interaction through messages', however the words 'Mass' and 'Communication' are still both not universally accepted by sociologists and are open to wide interpretation (Sorlin, 1994). When considering mass communication and the strategies needed to use it effectively it is important to understand the different models that exist.

There have been many proposed models of mass communication including the 'Lasswell formula' (1948) and the Watzlawick-Beavin-Jackson model (1967). McQuail states that there are four overarching types of model of communication that incorporate these disparate individual models: Transmission, Ritual, Publicity and Reception (McQuail, 2000); these are discussed in the next section.

4.2.1 The Transmission Model

The transmission model was the first model proposed and is described as a 'process of transmission of a fixed quantity of information – the message as determined by the sender or source'. Harold D. Lasswell proposed an example of the transmission model in 1948 when he started an article with:

Who;

Say What;

In Which Channel;

To Whom;

With What Effect (Lasswell, 1948).

This has consequently been known as the Lasswell formula and describes a simple linear process (Fig 15) to organise the communication process.

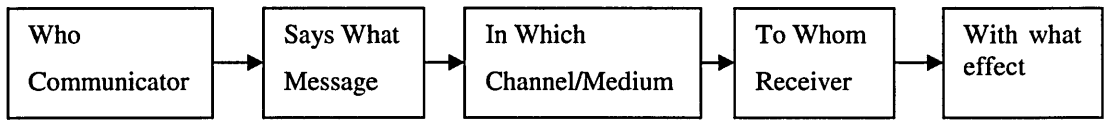

Figure 15 -Lasswell formula

The transmission model has been adopted as the standard model in mass communication. When it was first developed it was seen as a 'hypodermic needle' whereby a small group of individuals could directly inform and persuade society en masse. There, are however, several problems with the transmission model, namely neglecting the communicator's role. It assumes that there is only a desire to persuade or influence (McQuail & Windahl, 1981). The other predominant assumption is that the delivered message will always have an effect on society.

This model was further developed by Westley & Maclean (1957) to recognise the need for receiver feedback (Fig 16) and also the realisation that the communicator is not generally creating a message rather transmitting it, from voices in society. This makes the model non-linear, as this feedback has a strong effect on the communication process overall which in turn creates a less mechanistic more accessible model. But at its root, success is seen as amount of information transferred rather than receiver satisfaction.

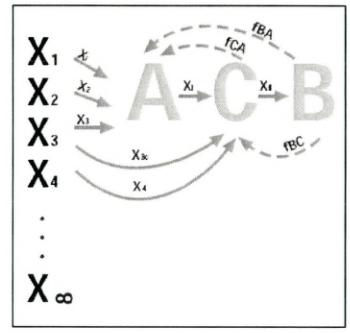

Figure 16 - Westley & Maclean Model, (1957) – Reproduced from Mitchell, (2004).

X's = Voices, phenomena, activity in society that generate communication

A= the Communicator, who are affected by the Xs

C= the Channel or Medium

B = the Receiver and the behaviour of effect that the communication has

f = Feedback from the various segments of the communication

4.2.2 The Ritual or Expressive Model

While the transmission model is primarily concerned with information dissemination, the ritual model is primarily focused on 'the representation of shared beliefs' (Carey, 1975). There is a need for satisfaction by the sender or receiver and does not itself serve an instrumental purpose such as in the transmission model.

"Communication is not directed toward the extension of messages in space but the maintenance of society in time; not the act of imparting information but the representation of shared beliefs ... the original or highest manifestation of communication [is] in the construction and maintenance of an ordered, meaningful cultural world which can serve as a control and container for human action." (Carey, 1975). This means that communication is engaged in for the pleasure of it rather than serving a utilitarian purpose and Carey argues that this form of communication is far older than other models. It uses the basis of the words such as communication, communion and community as an extension of ritual communication. An example of this is that a newspaper does not have to send or receive the information within, the process of reading the newspaper itself is an act or ritual communication (Carey, 1975; Karvonen, 1992).

4.2.3 The Publicity Model

This model is the primary communication approach and is used to catch or hold the public's attention; the most common examples of this model are advertisements, whereby there may be no information transferred or any common or shared belief and the only purpose of this communication is to gain attention, this being a marker of success rather than the quality of attention. Elliot (1972) stated that 'mass communication is liable not to be communication at all in the sense of the ordered transfer of meaning, it is more likely to be spectatorship and the media audience is more often a set of spectators rather than participants or information receivers'.

4.2.4 The Reception Model

The final type of model as outlined by McQuail is the Reception model and is realised through the viewpoint that there are many diverse receivers who do not distinguish messages as 'sent' or 'expressed'. This model, unlike the other three models, aims to totally empower the receiver, which is totally overlooked in the traditional transmission model (Lasswell, 1948). The Reception model is highly correlated with Reception analysis,

which focuses on the way that individuals make meanings of media messages and has developed to be associated with the view that audiences are dynamic and concerned. Recent work has focused on the way that audiences resist the approaches preferred by the mass media and create their own that are often contradictory. In Reception analysis, audiences are seen as 'active producers of meaning' not consumers of media meanings (Underwood, 2004).

This approach is seen as very different to the traditional transmission model and as McQuail states is not seen as having a limitation on the transmission model rather it is 'part of a quite different perspective' (McQuail, 2000) which appreciates the polysemiology of all messages generated and the way that receivers can change or decode the meaning of the message in different and disparate ways. To clarify, polysemiology means that all communications have many different signs, symbols or interpretations which change depending on who the receiver (s) is.

4.2.5 Summary of Models

To summarise the four models can be described as thus:

Transmission – Transfer of information, the message defined by the sender or communicator;

Ritual of Expressive - the representation of shared beliefs - does not itself have to serve an instrumental purpose;

Publicity – to catch or hold the publics' attention – the marker of success is attention itself, not quality of that attention;

Reception Model – empowers the receiver – receivers are active producers of meaning of messages, appreciates polysemiology of communications.

From the review of the four model types it can be seen than in the context of both the requirements in COM 581 and also the increased spirit of engagement with European citizens as shown in Chapter 2 that the reception model is most useful for this research. This model type engages actively with the user and seeks to develop communications that actually work with the consumers of the information. Engaging citizens is critical in creating understanding and is central to COM 581 and through this the BWMF. The Framework needed to use the most effective communication methods and as the review

above of the four models shows that simply publishing scientific data is not enough, as verified by Staines (2002) in Chapter 2.

Once the theoretical models of communication are understood the next stage of realising effective communication is to develop a communication strategy that will relate the model(s) to practical factors involved; the message, the audience/receiver and the channels/medium.

4.3 THE MESSAGE

The first and most important aspect of any communication strategy is to develop the intended message and there are a number of aspects to consider when doing this. Sorlin (1994) uses the common origin of the word text and textile to say that a message requires a number of elements that are culminated to create an 'autonomous product'. Messages are in two states, the actual printed text or news headline and the meaning that is embedded in the message, which will vary between individual receivers and groups. This is similar to European law where there is the actual form or text of the law and there is also an underlying ethos or sprit of the law. Understanding this is critical in developing a coherent message and communication strategy. In developing a message it is important to maintain consistency with all output; there should be no inconsistent data, viewpoints or emphases as this can lead to mistrust and lack of integrity to be associated with the sender, which could ultimately erode the original message and the meaning (EC, 2004).

In risk communication of environmental factors, of which this area of research is primarily concerned there are five aspirations of communication that can be developed and selecting the right one, defines the message and the strategy overall, these are:

- Building trust in the communicator/sender;
- Raising awareness;
- Educating;
- Reaching agreement;
- Motivating action (Rowan, 1991).

Bier (2001) states that when embarking on a risk communication that there are a number of points to follow to ensure effective message communication and validity:

- Legal requirements or organisational policies that may constrain the design of the risk communication message and/or format;
- The purpose of the risk communication – see bullet point above;
- Different risk communication strategies as appropriate – visual aids, books, posters etc;
- The characteristics of the audience(s) for the risk communication – educational and social needs.

In scientific and risk communication there is a large divide generated between scientists and the public, with a view that the public is largely ignorant of scientific knowledge and advances and is the thus 'deficient', and science is 'sufficient', this is called the 'deficit model' (Sturgis, 2004; Burns, 2003).

This has become much more prominent in recent years with several large issues such as genetic modification (GM), Bovine Spongiform Encephalitis (BSE) and Foot and Mouth Disease highlighting the lack of scientific education in the media and the lack of the scientific community's communication to the general public. The deficit model defeats every aspiration of risk communication (Rowan, 1991) and as such is not useful for further engagement with citizens, which is fundamental to this research. Therefore Competent Authorities need to develop appropriate messages for all stakeholders and realise that they cannot just transmit information to them like using a hypodermic needle.

A SNIFFER report (1999) reinforces that to create an effective message any communication of risk to the stakeholder needs to encourage:

- The need for two way communications;
- Transparency to create trust; and
- Openness to enhance the legitimacy of the overall process to the stakeholder.

Understanding risk communication is a large discipline in its own right, however it is important to remember the tenets above as a key part in the overall communication strategy. This helps to create the best possible methodologies and approaches.

It is equally important that the message provides the information that it intends to and that it is personally relevant to the audience/receivers (Rohrmann, 1992). To develop personally relevant messages and effective communication, understanding the intended and unintended audience is vital.

4.4 THE AUDIENCE

The 'audience' is a collective term for 'receivers' and was first used with the advent of the primary research models established in the 1950s e.g. The Schramm Model (McQuail, 2000). In early communication models and even until recently the audience was seen as a homogenous entity that would receive the messages that were communicated to them and then use this in the way that the sender planned. However, as shown in the reception model (4.2.4), this idea is outdated, does not realise the heterogeneity of the audience involved (Burns 2003) and can lead to the audience becoming demoralised and feeling manipulated (McQuail, 2000).

There are many definitions of audience and the sub-groups that form it and these change depending on the context of the research that they are related to; McQuail categorises the audience in a theoretical manner composing:

- The 'Available' or potential audience – with the basic skills (e.g. literacy) and the ability to receive;
- The 'Paying' audience – who actually pay for media products such as books, video etc;
- The 'Attentive' audience – those that actually read ,watch or listen to content;
- The 'Internal' audience – those who pay attention to only certain types of content, such as the news or a soap opera for example;
- The 'Cumulative' audience – the proportion of audience potentially reached over time;
- The 'Target' audience – the audience singled out for a certain 'message' such as advertising.

(McQuail, 2000)

This theoretical approach to the audience however, is too vague when relating to risk communication and scientific communication overall. Burns (2003) goes further when describing the groups or 'publics' within the deficit model approach and describes the following six groups:

- "Scientists: in industry, the academic community and government;
- Mediators: communicators (including science communicators, journalists and other members of the media), educators, and opinion-makers;
- Decision-makers: policy makers in government, and scientific and learned institutions;
- General public: the three groups above, plus other sectors and interest groups. For example, school children and charity workers;
- Attentive public: the part of the general community already interested in (and reasonably well-informed about) science and scientific activities;
- Interested public: is composed of people who are interested in but not necessarily well informed about science and technology.

(Burns, 2003)

These definitions of sub-groups start to become much more focused than McQuail suggests and provides a tangible resource when assessing the deficit model, which in turn creates a practical application that can be resourced for future work. The definition of audiences most relevant to the research is proposed by Rohrmann (1992) and is specifically related to risk and its communication. It also consists of six distinct groups within the audience and Rohrmann terms the groups as 'actors':

- Risk-exposed people;
- The general public;
- Industry/manufacturers/companies – such as Catchment Ltd.;
- Administrative/regulatory authorities – such as SEPA or Angus Council;
- Media ;
- Scientists, Academics.

The first two groups or actors for the bathing waters work could be merged as everyone in society can potentially use the bathing waters and thus all become risk-exposed. This list highlights the many issues and viewpoints that need to be realised for a communication strategy to successfully work. Within the European Union in the 5th Environmental Action Programme (EAP) there are specific requirements to reach the broad audience and realise societal and educational needs (EC, 2004).

To summarise, there are many stakeholders relating to bathing waters and as such the audience is large and complex and any communication strategy needs to be aware of this and needs to adapt to this. With a message defined and the audience realised, it is critical to complete the strategy by understanding the tools and methods available to effectively utilise them. These are called the channels or mediums and can greatly affect the communication strategy.

4.5 CHANNELS/ MEDIUMS

Communication channels are the medium that information is communicated through, such as the Television or Internet. There are large differences between the available mediums and it is important to make sure that the right one(s) is/are chosen. The traditional mass media consists of the Television, Cinema, the Press and Radio and as such has delivered much of the environmental information previous to the advent of new technologies, in particular the Internet. It should be noted that before the advent of Television and widespread radio broadcasts, cinemas were a valuable source of information and was still used as a valid news format until the 1960s. This has been replaced by Television and Radio since the last half of the 20th Century. Communication channels are constantly in flux and have been so since society first moved from oral communication to written text 7000 years ago (McLuhan, 1964).

Figure 17 shows the main sources of scientific information used by United Kingdom citizens (n= 1000) as surveyed by the well-established Eurobarometer program within the EU, this was carried out in 2001 and is the most current EU wide data (EC, 2001).

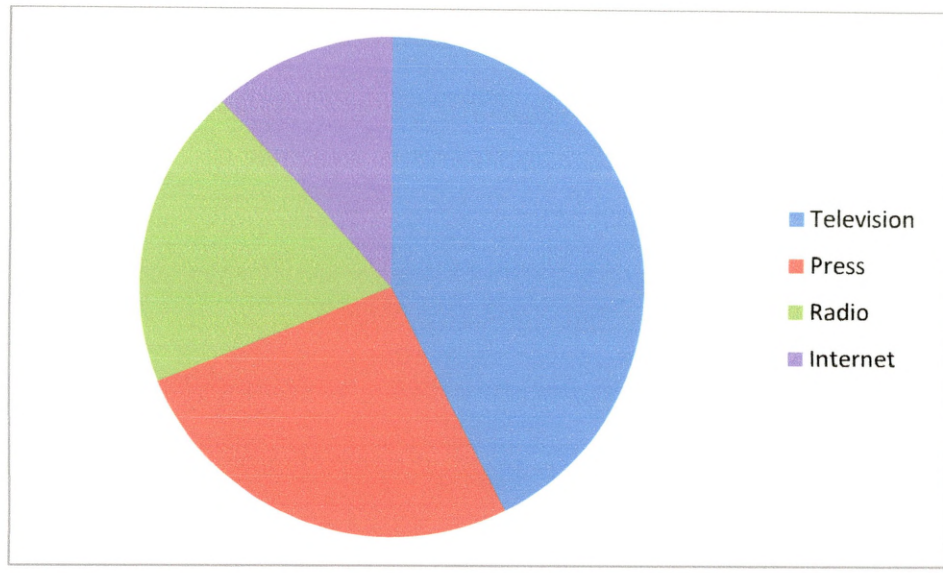

Figure 17 - Graph to represent percentage of respondents for each communication channel

Europe-wide data (n = 16029) for communication channels are very similar to the United Kingdom subset with the following percentage per channel; Television 42.55%, Press 26.24%, Radio 19.36% and the Internet 11.84%.

From 2001 to 2005 citizens' getting 'online' in the UK grew from 39% to 59%, and is constantly rising (currently 65%, (UK, 2008)), due to widespread promotion by the UK government and is in line with the rise of other new media technologies such as mobile phones, mobile computing and wireless communications (UK, 2005). With all of these channels available to the communicator it is important to realise 'differential audience reach' (Fig. 18) and knowing of this is vital for developing the overall strategy.

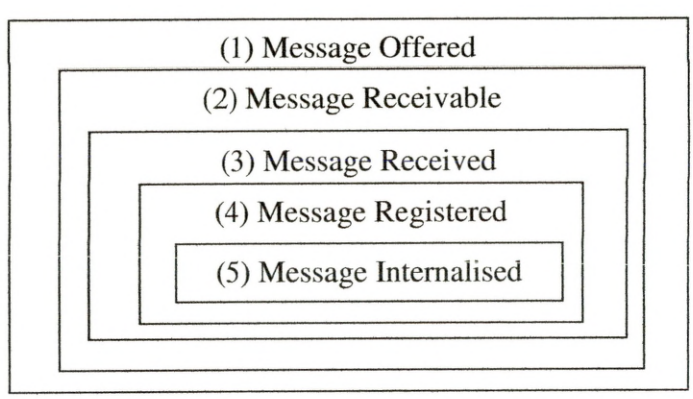

Figure 18 - Differential Audience Reach – (Clausse, 1968)

The first largest box is the total potential audience that can be reached and Box 5 is the actual audience that internalise your message. This diagram aptly highlights the massive wastage that communication produces, showing the value of developing an effective communication strategy.

With the substantial progression of the Internet and its relative ease of use and minimal costs, communicators are neglecting other mediums that are available to them and this can disadvantage certain societal groups such as the very young, the less educated and the less wealthy (Collins and Zoch, 2001).

4.6 CONCLUSIONS OF REVIEW AND SUBSEQUENT CHOICES

This section summarises how informational requirements created through the changing ethos of European environment law drove the choices of available mass communication models, messages, audience profiles and channels/mediums for the use with the Directive ultimately.

From the review it can be seen how complex communications are and how much they integrate into everyday life. Without appropriate communications used within the BWMF, the other components would not be required because the framework would fail. This means that choices made for communications directly links with the other disciplines. Biological data may be generated and non-technical summaries drawn up but if stakeholders cannot find these items then they are ultimately ineffectual outputs.

From the four models available; Transmission, Ritual, Publicity and Reception, it can be seen clearly from the literature that the Ritual model is not appropriate for the relaying of scientific information due to it not concerning an actual instrumental purpose but engaging both sender and receiver in a shared belief for pleasure rather than a strictly utilitarian process (Carey, 1975). The Publicity model is also not relevant for the purposes of COM581, due to its primary goal of generating attention, with little regard for the actual quality of information relayed. This is critical for the Framework. The original transmission model as stated by Lasswell (1948) is also not appropriate due to European informational requirements to engage the public and shape the communication strategy according to the needs of the audience. This is asymmetric to the basic transmission model which is to persuade and influence. However, Westley and MacLean's (1957) adaptation to the transmission model is useful to this research as it has an element of receiver feedback,

whereby the message can effectively be shaped by its audience, however it is still based primarily on the idea of transmitting information rather than the satisfaction it delivers to the audience. Finally the Reception model with its link to reception analysis sees message receivers as active producers of meaning, not consumers of media meanings. This model would allow each user to change and adapt the message that they are receiving to their own needs and as such the overall communication strategy would need to take into account each possible user and, as discussed previously within this chapter, anybody is a potential stakeholder in the revised Bathing Waters Directive.

In conclusion the best model is the Reception model. However, in terms of practicality the Westley and MacLean modified version of the Transmission model is more appropriate and can be applied more readily by competent authorities, to which this research is primarily aimed. Therefore the communication strategy embraced the ethos of the Reception model in terms of the appreciation of the receiver and was followed as much as practically possible. In terms of relaying specific information as required in the Directive, Westley and MacLean's (1957) adapted Transmission model was used, to maintain trust with the audience (EC, 2004).

With the model of mass communication chosen, the message is next step in the development of a communication strategy. The most important aspect of any message is that it is accurate and coherent as this increases trust (Sorlin, 1994) in the sender by the receivers, which is critical in risk communication (Rowan, 1991). This is intrinsic to the Directive's aims and objectives (EC, 2002). With regard to the aspirations of risk communication (Rowan, 1991), for this research and the Directive overall, 'building trust in the communication/sender' and 'raising awareness' are the most important aspirations and as such the message needs to be clear and cohesive and reported effectively. These aspirations whilst important need to fit within certain practicalities (Bier, 2000) to ensure that the message is fully effective. It needs to fulfil the basic text of COM 581 and should excel in reflecting the changed communication to the public that has occurred in Europe over the last 30 years.

With regard the audience for the communication strategy, it is clear that anyone can be a potential member/stakeholder of COM581 and as such the strategy needs to engage as many members as possible. Therefore this research as it relates to risk communication uses Rohrmann's definitions (1992) of the audience and the 'Actors' (Risk-exposed people, the

general public, Industry/ manufacturers/ companies, Administrative/regulatory, Media, and Scientists and Academics). Chapter 5 discusses how through the Framework, each 'Actor' can access the level of information they require.

Finally, with the key theoretical aspects of the strategy decided, the practicality of the mediums to be used needs to be addressed. It is critical to remember that, as this will be contained within a regulatory scheme, cost and timeliness need to be appreciated fully. Without these considerations, Competent Authorities would not be able to implement the strategy, which is the whole purpose of the research. With this in mind, television was discounted due to the large costs associated with it, typically £1000 per 30 second advert in the Grampian Television region of Scotland (TV-AYE, 2006) and the amount of times a report on water quality status may be needed in a bathing season, e.g. at least once a week for 15 weeks. Cinema was excluded for similar reasons. It was decided that the Internet would be the primary medium within the research, due to the large audience (59% of the population), large formatting options and relatively small costs, however to fully engage all potential stakeholders, a paper copy of the water quality data was also available. To increase awareness of the research and subsequently to have a greater audience reach, radio and newspaper journalists were actively engaged. This proved a highly cost-effective method of increasing awareness and details of this can be found in Chapter 5.

With the communication strategy fully developed, this was then implemented as part of the framework for COM581.

Full details of how the communication strategy was realised are presented in Chapter 5.

CHAPTER FIVE - THE BATHING WATER MANAGEMENT FRAMEWORK

5.0 PURPOSE OF THE CHAPTER

Chapter 5 represents the efforts of the total research project. Figure 19 from section 1.4 shows how each component of research feeds into the Bathing Water Management Framework. This tests: 1) that the objectives and associated research components fulfil the aim of the research and 2) if and how interdisciplinary research works and what can be learned from this novel approach.

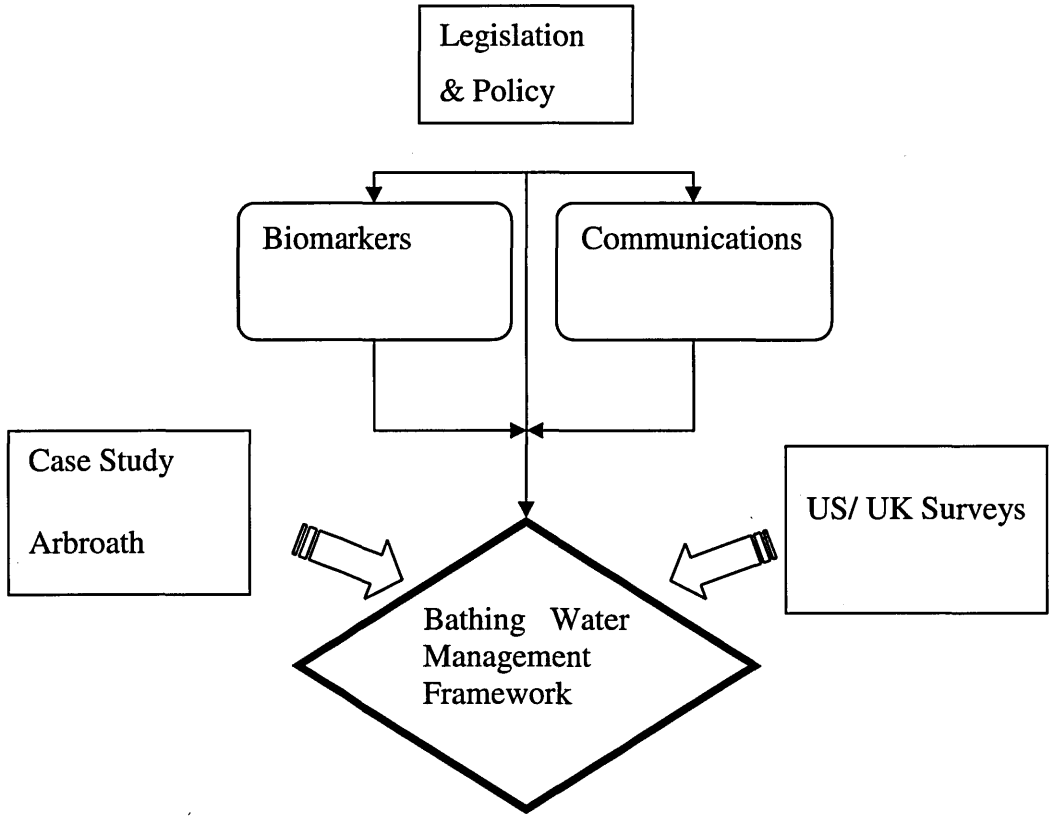

Figure 19 - How the various disciplines integrate to produce the BWMF

5.1 INTRODUCTION

This chapter details the Bathing Water Management Framework which is the crux of the research. In this chapter the purpose, definition and structure of the framework are outlined and discussed. The Framework's foundation lies in the previous chapter's disciplines; law, biomonitoring and communications. The second part of the chapter describes the practical

testing of the Bathing Water Management Framework which was applied to the Arbroath Bathing Water from August to October 2005.

5.2 PRINCIPLES OF DEVELOPMENT

Using in depth understanding of the law review as a starting point, the 'framework' delivers the requirements of the revised Directive through a 'toolbox' consisting of the individual methods developed, e.g. biomonitoring.

5.2.1 Why use a framework?

The word 'framework' is used in various ways such as the Water Framework Directive and the Bournemouth Coastal Management Framework (Bournemouth Council, 2006). The Cambridge dictionary delivers a very succinct and useful definition which states that a framework is 'a supporting structure around which something can be built' (CUP, 2005). This definition, however is not complete as the Bathing Water Management Framework is not just a supporting structure for the 'toolbox' of methods in the research. It is the crux of the research and as such a reference from the American Heritage Dictionary of the English Language is much more relevant 'a set of assumptions, concepts, values and practices that constitutes a way of viewing reality' (AHD, 2004). The BWMF is a way of viewing the overall concept and requirements of the Directive and thus generates a reality due to the practical objectives that have to be delivered in the Directive. Using a framework in interdisciplinary research is crucial. An anonymous quote in Lattuca's 'Creating Interdisciplinarity' (2001) states that, 'I think of interdisciplinarity as the creation of new intellectual space .... It's more than the combination of the individual disciplines' (p.98).

As stated in Chapter 1, conceptual interdisciplinarity is where the research question has no compelling disciplinary basis (Lattuca, 2001). The main aim of this research 'to assess the legislative and managerial development of the Bathing Water Directive proposal COM 581 and to develop methods and approaches to support this, through the production of a Bathing Water Management Framework (BWMF)' is an example of this. The Framework is needed to deliver a practical management system using the work from the other chapters. When assessing other research that has used frameworks for delivery it can be seen that they are used in similar ways. Hackney (2006) uses a framework to 'tie together' nine factors used for evaluating web services. Herrick et al. (2006) use a framework 'for organising, synthesising, and applying the evolving understanding of arid land

ecosystems'. The reason for choosing to use a framework for this research and the delivery of its outcomes once again resonates with the AHD (2004) framework definition 'a set of assumptions, concepts, values and practices that constitutes a way of viewing reality'.

5.2.2 How was the framework created?

This development of methods and approaches in support of the revised Bathing Water Directive would not be possible using just the COM 581 document as stated throughout the thesis. It is important to remember why the research was carried out: to develop methods and approaches to support COM 581 through the BWMF. These are outlined in the law review in Chapter 2 and summarised in Table 14, together with the corresponding article or annex, from COM 581.

Table 14 - Table of required outputs from COM 581

Article	Information Details
Annex III	**Map of Bathing Water with Pollution Inputs** – as part of the Bathing Water Profile, a detailed map showing sources of point and diffuse pollution, both quantitatively and qualitatively
6	**Bathing Water Profile** - Consisting of information on the bathing water location, pollution sources, a map showing these sources and inputs and a description of monitoring points
7	**Monitoring Calendar** – A list of dates of water quality monitoring, made public at the beginning of a bathing water season
7	**Water Quality Data** - Monitoring water quality as set out in Annex I and other such methods where needed
16	**Non- Technical Summary-** A summary of the overall bathing water. Designation and other pertinent information related in lay terms.
16	**Pollution Incident History** - of incidents, requiring management measures

These requirements help to structure the framework and the subsequent delivery of the aims and objectives of this research. Chapter Four shows that using a publicly accessible website as a portal was the preferred method of communication due to the large available

audience (59% of the UK in 2005, 65% in 2008) and cost and design considerations. COM 581 only states that competent authorities 'shall use appropriate media and technologies'.

For the portal to be usable the requirements were allocated to certain topic areas. The decision to base the framework around a website portal is further justified by looking at the framework in context of the findings of the law review in Chapter 2, as the communication and dissemination of information to the public forms a large part of the changes to the Directive.

This also delivers the requirements for active management of bathing waters through the inter-related outputs discussed. Each of the requirements in Table 14 was classified under topic areas that could be accessed by all stakeholders. This allowed access to the framework, to the area and at the level of detail required. Table 15 shows how the requirements in Table 14 were categorised into topic areas.

Table 15 - Requirements classified by topic

Topic Area	**Information within topic – each page detailed**
Water Quality Data	**Microbiological Data** – as established in BWD 76/160 and still required in COM581, sourced from competent authority (SEPA) **Biological Monitoring** – Research data see chapter 3 for specific details **Methods** – detailed methodologies of methods SEPA's and methods developed in Chapter 3
Location Data	**Map Of Location** – Map of designated bathing water Bathing Water Profile Pollution Incident History
Official Documents	Non- Technical Summary Monitoring Calendar

Using these topic areas, a basic framework was created with a standard website design (Figure 20) utilising a wide hierarchy. This gives the user a wider set of choices at the front of the framework and then less levels of depth. This is opposed to a narrow hierarchy

where limited choices are available initially with greater levels of depth further into the framework (Veen, 2001). With a well defined set of requirements, the main disadvantage of wide hierarchy systems, that they are too broad in the initial stage, was overcome. This meant that the framework was accessible to all stakeholders. Further details of the practical website portal creation can be found in Appendix 2.

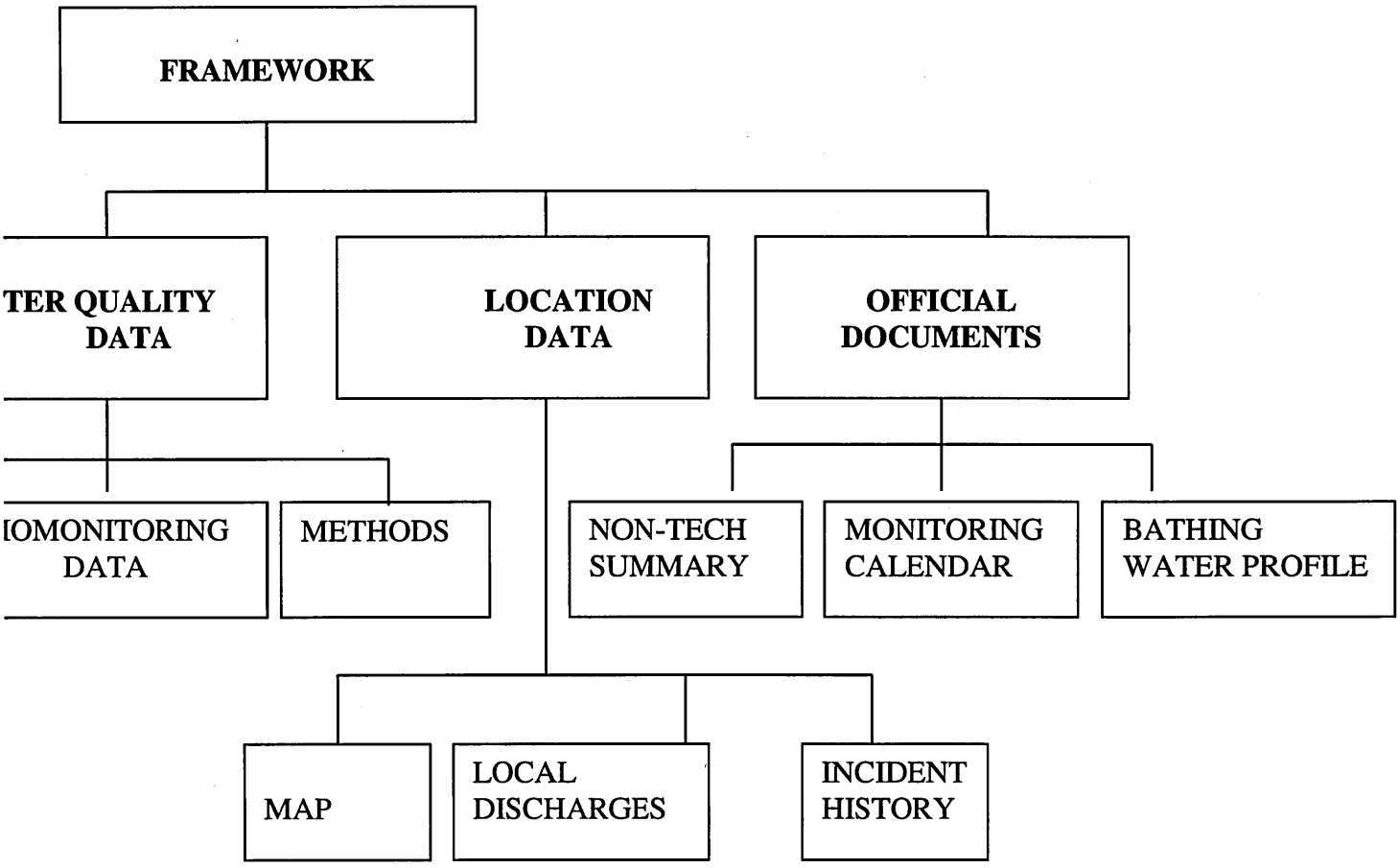

Figure 20 – Portal structure based on Bathing Water Management Framework

The framework website was created using Dreamweaver MX 2004, following standard web conventions established in Powell (2000) and Nielsen, (2000), two industry standards in web design. The framework comprises the components as shown in Table 14. These components were then populated using the various inputs gathered from the research and related networks discussed briefly in Table 16.

Framework Component	**Input**
Microbiological Data	These data were supplied by SEPA on their website.
Biomonitoring Data	These relates to the biomonitoring process as discussed fully in Chapter 3
Methods	This describes the above methods, in line with increased information to stakeholders
Map	As part of the Bathing Water Profile. Created using information from SEPA collaborative research (2004) and Staines et al.,(2003)
Bathing Water Profile	Created using information from SEPA collaborative research (2004a) and Staines, et al.,(2003)
Incident History	Incident data was supplied by SEPA and Catchment Tay when it occurred with length of incident, volume of spill and time and dates
Non-technical summary	This was created in accordance with the requirements in the Directive
Monitoring Calendar	This was created using the schedule for the biomonitoring as discussed in Chapter three

Table 16 - Table showing framework components and related inputs

These framework components in terms of the communication strategy deliver the message that it is about 'building trust in the communication/sender' and 'raising awareness', as determined in Chapter 4. This also follows the principles of the Modified Transmission model which allows users to provide feedback into the communications that they are receiving. This manifests in the choice of hierarchy in the portal layout.

These components through the framework portal appear to fulfil the revised Directive's requirements. However, testing is required to establish if the framework is appropriate and of use to the stakeholders who are ultimately the audience. Results of the finalised framework and its live running during the 2005 bathing water season can be found from Section 5.3 onwards, within this chapter

5.2.3 Is a Framework portal the right way forward?

In the UK, the control and regulation of the inter-tidal zone generally is fractured. Indeed when referring to the 'foreshore' McGlashan, et al., (2005) state that there are many different definitions in law and geomorphological terms alone, depending on how one defines the foreshore. This obviously means designated bathing waters which are within the foreshore have a number of different agencies and local authorities providing various services and regulation. For example, in Arbroath, the Bathing Water lies within the County of Angus. Angus Council is responsible for cleaning the beach area and carrying out protective measures against coastal erosion such as building sea defences. The Crown Estate 'owns' the beach from the High Water Mark to the Low Water Mark and controls works carried out on it. SEPA then monitors the Bathing Water for water quality standards and from the results can then penalise the local authority, water providers or whoever may be responsible if there is a degradation of bathing water quality. Further, if actions carried out by these parties endanger biodiversity then action can be taken by other agencies. In Scotland this is Scottish Natural Heritage (SNH). There are other layers of regulation including planning authorities and port authorities, all of whom control various aspects of the inter-tidal zone. At this stage there is no concerted effort to work together, instead concentrating on their particular sector. Integrated Coastal Zone Management (ICZM) is trying to address this but progress is slow (DEFRA, 2006). As of 2009, DEFRA stated that ICZM principles were embedded into the UK Marine and Coastal Access Bill which is still going through parliament, but it is not explicitly stated (HOL, 2008)

This demonstrates that a universal portal of information on bathing waters is needed to deliver all aims of the revised Bathing Water Directive. This would provide a central repository of information accessible by all agencies and bodies. This is a key deliverable, not only in bathing water management but also in addressing the ways to approach coastal management in Scotland and the EU as a whole.

There is no single point of contact for beach management in the UK or EU generally and as such it is difficult to see who to approach for the assessment of the portal framework. It was decided that the sponsors of this research would be appropriate as they represent a true cross-section of authorities and stakeholders these being, SEPA, Angus Council and Catchment Tay a local wastewater management company in charge of sewage release within the catchment area around Arbroath bathing water. The three members of these organisations who represent the sponsors were questioned on how they would like the framework to be assimilated with regard to their organisation's requirements.

When questioned on how they would like to access the information all respondents stated that Internet based information would be one of their preferred options. This result helps to verify the literature and thus the framework choice of hosting a portal. Also asked was how the respondents would like the information to be structured, either; in alphabetical order, by article (i.e. using the articles contained within the Directive text) or by an overarching topic area. All respondents chose by topic, thus verifying the choice of collation as described in Table 15. Overall general comments from the survey revealed that the respondents would like a "simple", "idiot-proof" and easily searchable framework, and this correlates well with the issue of poor information at present as highlighted by Jules Maaten in Chapter 2 of this thesis (p.40).

Single point management of beaches is not carried out in the UK or EU but it is carried out in various states within the United States, with well developed beach management policies. The most progressive of these states is California, which enabled the Californian Coastal Act (CA, 1973) in 1973. Through the California Coastal Commission, the Act requires each coastal county to develop a local coastal programme which should take into account all factors such as economic development, tourism and environmental stressors. This work is implemented through individual beach managers who have overall control of the beaches; this shows the practical application of interdisciplinarity being applied to beach management.

It was decided that engaging with Californian beach management parties would improve the research by seeing the lessons that have been learnt. Professor Karen Martin of Pepperdine University, Malibu, California, a prominent beach management researcher, was contacted. From this, a month long visit to Pepperdine University was organised. Work was carried out consisting of informal talks, meetings and seminars with beach managers, academics and policy makers throughout California. Data were gathered through qualitative and quantitative surveys.

The first meeting attended was with the Santa Monica Bay Restoration Commission – Technical Advisory Group (SMBRC – TAG). This meeting comprised local academics, regulators, industry representatives, NGOs and other stakeholders, is similar to the Scottish Tay Estuary Forum (TEF) in format. This group enables decisions to be made with all major stakeholders having an input, which is then fed through to beach managers.

This group demonstrated that within Scotland, fora such as the TEF could be used to drive ICZM in the future, if properly supported. Throughout the visit it was established that there were strong relationships between all stakeholders involved. This creates a network of expertise and minimises conflict. There are far more beach users in California than in Scotland, due to the drier, warmer climate. For example David Pryor, an ecologist for Orange County stated that Huntington Beach alone receives 17 million visitors per year, with 1 million visitors attending Huntingdon on the 4th of July alone. This increases the interest and resources placed towards the beaches in California. In comparison the most users recorded on a Scottish beach in 2004 was 200 (SE, 2004).

To gain data a survey of beach managers and other people directly in charge of beaches was carried out. The survey contained 9 qualitative open ended questions and 15 quantitative ranking statements. The information behind the survey, which can be found in Appendix 3, was generated from questions posed from the literature of the various components of the framework. The survey helped to show how US beach management may differ from European approaches and make the framework more robust. Once again it should be stated that there are no designated beach managers in the UK/EU and as such the data were invaluable.

The managers scored each statement by marking on scale of 1 to 9 how much they agreed with it, 1 being the lowest and 9 being the highest. Table 17 shows the number of managers marking the statements at each level of agreement. When a linear scale is used to

gather responses it is important to see how in this case each statement ranks in terms of each other, the relative importance of each statement overall to the research. A useful approach to this is to use a Relative Importance Index (RII) (Mezher and Tawil, 1998) which is the arithmetic mean of value of scale, which can be calculated using the following formula;

$$Relative\ Importance\ Index\ (RII) = \frac{\sum NiSi}{\sum Ni} \quad \text{.....(Equation 5.1)}$$

Where RII = Relative Importance Index

Ni = number of responses on respective scale; and

Si = Respective scale (1,2,.....9)

Table 17 has been ranked by the descending relative importance of each statement. This allows interpretation of the data in relation to the BWMF and how it correlates to an existing holistic bathing water management approach.

Table 17 - Table showing survey responses

	agreement									
Statement	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**RII**
Microbiological data are critical to public safety	0	0	0	0	1	0	1	5	12	8.42
The Internet is a useful communication tool	0	1	0	0	3	0	2	3	12	7.76
Diffuse pollution is the biggest threat to water quality	0	0	0	0	3	1	2	4	7	7.65
American Beach Management is primarily focussed on human use	1	0	1	1	2	0	0	8	7	7.25
Independent policy advice would be worthwhile	1	0	1	0	3	0	5	5	5	6.95
Scientific data are too complex for the public	3	0	0	1	2	1	2	5	8	6.77
Local fauna and flora are a good indicator of overall beach condition	1	1	1	0	3	1	1	3	7	6.72
The public are interested in the management of beaches	0	2	1	1	1	1	2	2	6	6.63
Beach management is better than scientific data alone	2	2	0	0	1	1	4	1	8	6.58
I fully understand policy decisions	0	1	1	0	4	3	1	2	5	6.53
Policy is clearly disseminated and communicated to you	0	1	1	1	4	1	3	5	2	6.33
Point source pollution is the biggest threat to water quality	2	1	2	0	1	2	3	3	5	6.16
Information to the public is well communicated	2	0	1	0	4	4	0	3	4	6.06
Inter- agency communication is well developed	3	0	1	2	1	2	6	2	2	5.63
Policy makers understand the practical issues facing me	4	0	5	1	4	0	4	0	1	4.21

Where it is relevant, qualitative answers are used to reinforce the quantitative data.

The top ranking statement by the managers was that microbiological data are critical to public safety. The qualitative data supported this finding, with many managers stating 'clean' and 'safe' as the most important issues to consider in US beach management. As stated earlier, beach usage in California is much higher than in the UK, with 53 identified beaches in Los Angeles County and Orange County combined. This is on a coastline of less than 100 miles. With the ambient weather conditions being more favourable than the UK there are also more water users, especially surfers (Leeworthy et al., 2007). It has been estimated that if all the beaches in this small stretch of coastline were to close it would lose the local economy $3.5bn a year and over 47,000 jobs (Leeworthy et al., 2007).

This finding shows how important rapid, accurate information to the public is. In California microbiological standards are still used as the main quality indicator and test water quality daily. This confirms the findings in Chapter 2 regarding people's desire for information (EU, 2003a) and also Chapter 4 where the need for effective, rapid, accessible communication is shown as paramount to the Framework's successful operation.

The second most important statement for the managers was the usefulness of the Internet as a communication tool and this ties in well with the first statement on microbiological data. Before the Internet, bathing water quality was displayed in paper form at the beaches, thus not allowing users to make choices of beach dependant on data. As stated by Jules Maaten in Chapter 2, within 10 minutes he could not find information on water quality across Europe. In California, many beach users visit the Heal the Bay Beach Report Card website for information on beach water quality, http://www.healthebay.org/brcv2/. Heal the Bay is an NGO that was formed into 1985 to address issues with Santa Monica Bay water quality at the time. Due to the joined up nature of beach management in California, Heal the Bay can quickly generate effective communication of beach status using the Internet.

The Beach Report site shows what could be achieved in Scotland with a joined up approach to coastal management. Using the Internet also corresponds to findings in Chapter 4 and also helps to confirm that using a web based portal for the BWMF is an effective approach to adopt.

The third most important statement is that diffuse pollution is the biggest threat to water quality and this restates the need for holistic water management due to the problems associated with quantifying this form of pollution. Using information from Bathing Water

Profiles will allow competent authorities to assess the most important sources of pollution to bathing waters and for them to take appropriate steps to remedy them. This also verifies that microbiological indicators alone are not enough for monitoring bathing water quality. Using rapid indicators such as those identified in Chapter 3 and deployed in Chapter 5 are needed to identify the ecological impact of upstream pollutants on the receiving water body. Using ecological population studies such as in the WFD will not work in such a short time period.

The survey respondents helped to drive the framework creation due to their existing knowledge of the interdisciplinary beach management approach. This also shows that the changes in law and management of European bathing waters being proposed are possible and can be run successfully.

The fourth most important statement is that American beach management is focused on human use and with large economic factors reliant on the beaches it can be seen why this may be the case. However, in this aspect Europe may be more advanced in its approach where management of water bodies is progressing to ecological status of waters and appreciating the ecosystem services that are provided by the water bodies.

The sixth most important statement on scientific data being too complex for the public verifies the need to move to the 'smiley' approach suggested by the commission and recently adopted by competent authorities in the United Kingdom since 2007. This also once again shows how important communication is for the public. As stated in Staines (2002) at the time only 41.6% of survey respondents (n=461) would look for SEPA data as it was in a very technical format.

Looking at the least valid statements, we can see that lack of communication is the key to all of them in several ways. The least important statement or the statement that most people ranked the lowest was "the policy makers understand the practical issues that face me". This is where interdisciplinary research can add significant value to the Directive transposition process. Policy makers have limited time to implement directives and typically have to deliver several directives in parallel which does not leave time to carry out exhaustive analysis of decisions made before national implementation. By utilising interdisciplinary principles and methods this would allow policy makers to see how things may and may not work practically. A key issue in SEPA is how each Directive is developed in several separate teams, e.g. information systems, charging schemes,

Geographical Interface Systems will all be developed individually and compiled at the end. By developing interdisciplinary teams consisting of members from various disciplines this would allow problems to be seen early on and make sure that the legislation has been implemented effectively. This approach can be seen throughout the thesis.

The second least valid statement was on inter-agency communication and this relates well to the least important statement. As discussed earlier in this section coastal management in Scotland is highly fragmented and this is surprisingly reinforced by this survey. As shown in the collection of data for the Bathing Water Profile later in this chapter (5.3), many organisations need to work together to create overall profiles of bathing waters and this can only be achieved by effective communication.

Finally, the third least valid statement states that information to the public is well communicated which is also surprising with the wealth of online information regarding California's beaches. This could relate to inter-agency working and shows how this needs to be in place for effective beach management.

The survey respondents helped to drive the framework creation due to their existing knowledge of the interdisciplinary beach management approach. This also shows that the changes in law and management of European bathing waters being proposed are possible and can be run successfully.

5.2.4 Summary of the Development

It has been shown that a framework is needed to implement interdisciplinary research and the literature and stakeholders support this view. Using the Internet and the development of a portal is also a valid approach. With regard to coastal management overall, the UK and EU needs to address the problems associated with current management systems and approaches and possibly look towards the US model as a suggestion of Integrated Coastal Zone Management (ICZM). The next section of this research looks at the framework deployed in the summer of 2005 and how the requirements from the Directive were realised.

5.3 DEPLOYMENT AND TESTING OF THE FRAMEWORK

So far this chapter has shown how the framework approach has been developed, with reviews of relevant literature and related practical testing of methods and approaches. It is vital to test the components together to fully understand the revised Directive. This is in line with the framework approach that has been built up throughout the research and is critical to the overall consistency of the work. This consistency is delivered through the portal framework which itself is a test of interdisciplinary research.

The research has shown that there are an array of requirements and issues to be addressed in the revised Directive. Consequently, the outputs of the research could be considered fragmented due to the wide range of disciplines and approaches used throughout the work. The research has attempted to meet the needs of the articles prescribed in the Directive. Yet this whole research is also being used to see if interdisciplinary research methods can be used successfully and what lessons can be learnt from this approach. There would be no framework output without the various disciplines deployed in this research.

So to provide a holistic assessment of the overall framework and its delivery the following sections use two approaches:

- assessing how individual components within the framework were delivered i.e. does the biomonitoring provide useful data on overall bathing water quality and feed into BWPs;
- the interdisciplinary challenges, considering if the overall framework added value to the stakeholders.

5.3.1 Individual framework components

This section presents the individual components of the framework as discussed in Table 14, required in the revised Directive.

5.3.1.1 Article 6 and Annex III – the requirement for a Bathing Water Profile and a Map of Bathing Water with pollution inputs

One of the biggest considerations for competent authorities when delivering the requirements of the revised Directive is the need for a Bathing Water Profile which must contain:

- a description of the physical, geographical and hydrological characteristics of the bathing water;
- an identification – quantitative and qualitative - of all potential sources of pollution;
- an assessment of their potential to pollute bathing water, thus impairing the health of bathers. This assessment should be made, in terms of time - accidental or chronic risk potential - and in terms of the nature and volume of all polluting and potentially polluting discharges and their effects assessed in terms of distance from the bathing water.

Elements a) and b) should also be provided on a detailed map.

Other relevant information may be attached or included as deemed appropriate:

- a description of the monitoring points;
- an assessment whether this monitoring provides as well representative information for other recreational activities practised with a similar risk of swallowing water as bathing (e.g. windsurfing, kayaking).

(EC, 2002).

This task is a large undertaking and requires an interdisciplinary approach. To achieve this, research was aligned with a SEPA study in the summer of 2004 (SEPA, 2004a) as part of a larger Environmental Improvement Plan (EIP) aimed at addressing failures of the Arbroath bathing water in 2002. Further to this, the development of the Bathing Water Profile drew on a study commissioned by United Utilities PLC in 2003 addressing the same failures of the Arbroath bathing water in 2002 (Staines, et al., 2003).

The main aims of both studies were to understand the failures of the Bathing Water, extensive work was carried out identifying sources of pollutants and their relative impact to the Bathing Water and surrounding catchment. These studies along with work carried out in this research, helped to create a Bathing Water Profile, for Arbroath. This joined up approach was utilised in this research, though with the open ended requirements of Article 6, competent authorities may need to address other ways to gather and co-ordinate this work.

Detailed below are the research findings from the SEPA Study (SEPA, 2004a), The Catchment Tay study (Staines et al., 2003) and biomonitoring carried out as part of this research, where it is relevant. The findings are presented to show how much work will be required by Competent Authorities. At the end of the data, the overall findings are discussed in the context of the Bathing Water Profile.

Within the SEPA study, riverine microbiological sampling and marine based dye tests at marine sewage outfalls were performed for the Carnoustie and Arbroath catchments. The specific work is summarised throughout this section. These data are a requirement under bathing water profiles within the Directive.

Sources of pollution relating to Arbroath Bathing Water

Following the study for United Utilities PLC (Staines et al., 2003) and a further study carried out by SEPA, work began on the four rivers that input to the Bathing Waters, two at Carnoustie and two at Arbroath, with SEPA carrying out a detailed survey of all possible pollutants upstream of the bathing waters. This identified inputs of both point and diffuse pollution - and 10 on average per river ranging from wastewater treatment plants to cattle urine and faeces.

Methods

The two methods used to identify the causes of bathing water failure were microbiological examination of previously identified sources of pollution and the use of dye tests to track how wastewater effluent disperses from the outfalls that extend into the sea around Arbroath and Carnoustie.

Microbiological examination of pollutant sources in selected rivers

Sampling points along the Elliot and Brothock waters were identified through previous scoping activities and contained a range of pollutant types. Figure 33 in Appendix 1 shows all locations referred to in this thesis. Water samples were collected at the above designated sampling points weekly, and then tested in the SEPA microbiological laboratory in Riccarton, Edinburgh, for Total Coliforms, Faecal Coliforms and Faecal Streptococci. These are the microbiological requirements for Bathing Water standards under 76/160. These were used to correlate the impacts of upstream pollution events and the resulting bathing water quality at Arbroath and Carnoustie. The standard methods for sampling, transporting and testing can be found in SEPA's 'Sampling of Water for Microbiological Analysis' (SEPA, 2004b).

Dye tests of wastewater outfalls

In the autumn of 2004, SEPA marine scientists carried out drogue and dye tests at each wastewater outfall that drains into the Arbroath Bathing Water to determine whether the outfalls impact on the Bathing Water. Rhodamine WT dye was used to estimate the dilution of wastewater that spills from Inchcape Short Outfall, how far and where it travelled. A Dye test was carried out on a flood tide on 1 November 2004. Prior to the survey, the dye (20% m/v soln.) was mixed with methanol to achieve the specific gravity of a freshwater. Two batches of dye mixture were prepared, with the total of 35 litres. The mixture of the dye to methanol was 1:1.36. The dye was released from a survey boat as two batches, both close to the Inchcape Short Outfall, close to the water surface within 30 minutes of each other.

Distinct 30 ml samples of seawater were collected after the batch release, covering the area between the point of release and West Links sampling point. They were later analysed in the laboratory, using a Turner 10-005 fluorometer and the results were compared with prepared dilution standards.

Four holey sock drogues were deployed at the same time as the dye to mark the dye patch. Drogues only were deployed on 2 November 2004 on the ebb tide to mark the water movement from the West links sampling point.

Results

The section presents the findings from the SEPA study of pollutants upstream in the Elliot and Brothock waters and the dye tests of the outfalls in relation to the previous Catchment study (Staines et al., 2003) where other sources of pollutants were identified.

Microbiological examination of pollutant sources in identified rivers

Elliot Water

Within Elliot Water, the main pollutant issues were thought to be diffuse from the widespread agricultural practice in the catchment with several herds of cattle present along the watercourse, most notably at the village of Redford and at the Black Burn tributary. Nonetheless due to the extensive nature of the study it was shown that the main cause of pollutant load into the Elliot Water was from human sewage from the hamlet of Arbirlot and was linked to rainfall triggering the spills (SEPA, 2004a). An example of this was on the 16th August 2004 when 1.2 mm of rainfall, was recorded at a nearby rain gauge. Upstream of the Arbirlot sewage treatment works a concentration of 2700 faecal coliforms per 100 ml was recorded, yet downstream of the works, a concentration of 41000 faecal coliforms per 100ml was recorded. Figure 21 shows that on other sampling days where there was a rainfall event, elevated FC levels were present downstream of the works. The graph shows rainfall event data series plotted against the y-axis FC/100ml and on the x-axis, the sampling points sequentially along the Elliot Water.

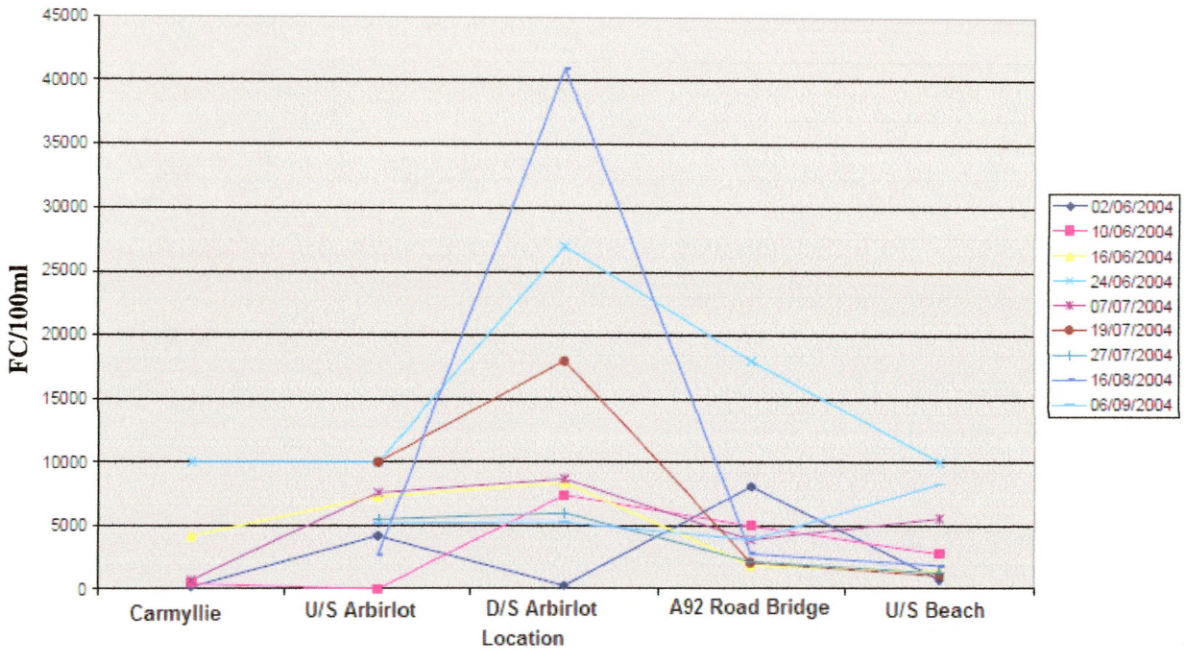

Figure 21 – Graph showing FC levels in the Elliot Catchment for selected dates (SEPA, 2004a)

Septic tanks from individual properties also contribute to the pollutant loading within the river. Where the river drains into the sea, there is a sandbar that forms a depression in which the river water is contained at low tide. This increases the time that ultraviolet rays from the sun can degrade the faecal organisms and reduces the final faecal concentration entering the bathing water (SEPA, 2004a).

Brothock Water

Within Brothock Water the causes of pollutant loading are much more obvious than with Elliot Water with various anthropogenic inputs including the sewage treatment plant for Letham Grange, septic tanks near St. Vigeans and, as the river travels through Arbroath, surface water drains. Once again at times of increased rainfall, faecal coliforms increased as the various outfalls were triggered as shown in Figure 22.

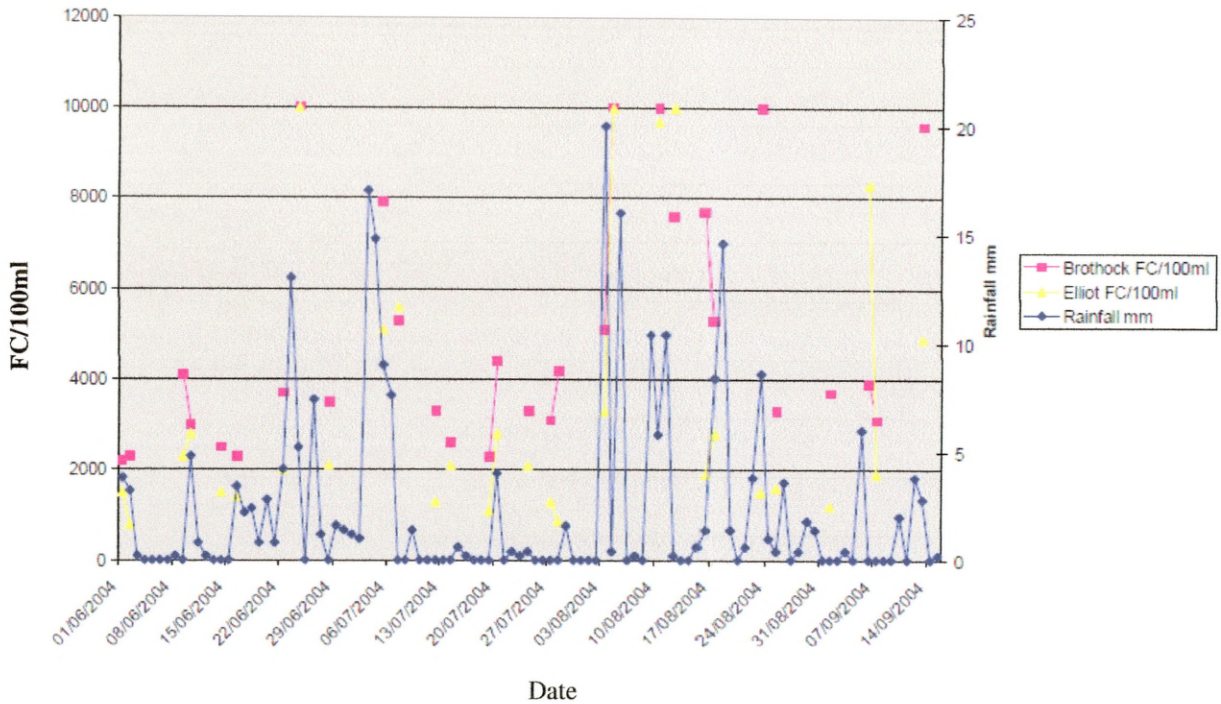

Figure 22 - Rainfall at Colliston Rain Gauge vs. FC Concentration in Brothock and Elliot Waters (SEPA, 2004a)

The Brothock then enters the sea at Arbroath, adjacent to the harbour, directly north of the bathing water beach.

Even though both the Elliot and Brothock Waters sometimes carry large concentrations of faecal organisms, they do not appear to be as significant as previously thought (SEPA, 2004a) and as such other impacts within the area had to be considered. These include various short and long sea outfalls that are located near the bathing water (Fig. 23).

The scoping study of possible inputs to the bathing water (Staines et al., 2003) showed that there are a number of sewage outfalls and other outputs that could affect the bathing water. Figure 23 shows that in a relatively small area there are eight possible sources of both diffuse and source pollution. Table 18 details each pollutant source. The blue arrows of Figure 23 (4&8) point towards the bathing sampling points at Arbroath and also at the recreational water monitored at Victoria Beach.

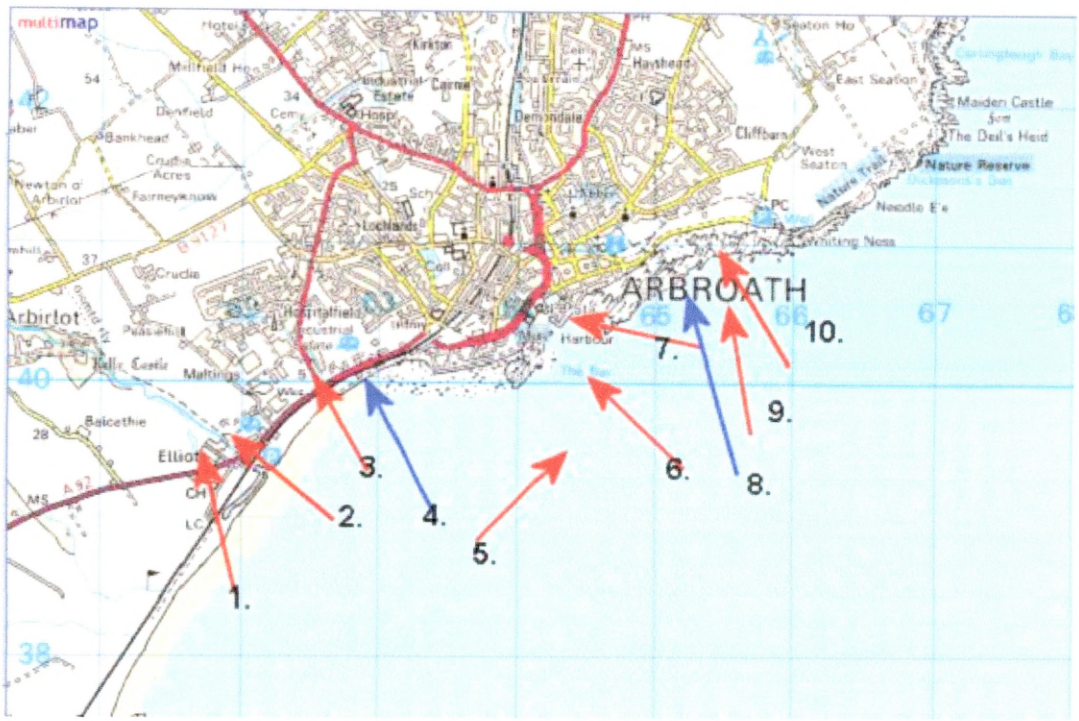

Figure 23 - Pollutant sources identified in 2003

Table 18 - Pollution Sources described

Number	Name	Description of Factors	OS Grid Reference (X,Y)
1	Elliot Outfall	Linked to several septic Tanks (Only works on extremely low tides)	361744,739541
2	Elliot Burn	Agricultural Run-off and sewage	Contact with Beach 361900,739400
3	Gordies Burn	Agricultural Run-Off and sewage	Contact with Beach 362600,739900
4	West Links	SEPA Bathing Water Sampling Point	363000,740100
5	Inchcape (L.O.)	Long Outfall – CSO	364160,739310
6	Inchcape (S.O.)	Short Outfall – CSO	364350,740150
7	Brothock water	Agricultural Run-Off & CSO	364400,740600
8	Victoria Sands	SEPA Recreational Water Sampling point.	365100,741000
9	Cliffburn L.O	Long Outfall CSO	365510,740902
10	Cliffburn S.O.	Short Outfall CSO	365500,740450

Of these sources, Elliot Water, Elliot outfall and Brothock Water have been identified in the study of 2004. Gordies Burn was discounted as not having a significant effect and both Cliffburn Long and Short outfalls were found to have little effect also. This is due to the Cliffburn outfalls only being permitted to discharge in emergencies and wastewater that previously discharged from here is now diverted to the Inchcape Park screening chamber (SEPA, 1996)

Dye tests of wastewater outfalls

It was observed during the survey, that in the beginning the dye was moving in quite a narrow flow, which slowed down and spread in both x and y directions. This happened at the approach of the bay. The dye patch moved towards the shore, where it was very evident 3 hours after the release. The drogues never travelled as far to the shore as the dye, suggesting a significant degree of shearing between surface layer and deeper water layer. The results show that the plume stayed at the surface, showing very little dye even at 1-metre depth. The minimum dilution of the water samples, taken from the boat was 4.3E-4, sampled at 400 m from the release location.

Most concentrated sample, nearest to the Bathing Water sampling point, had a dilution of 4.5E-5 at 250 metres to the west of the sampling point. Shore samples show that dye was advected to the beach and was very evident, covering a large area close to the shore. The minimum dilution measured was 3.4E-6, 3 hours after the release. Some dye tracks showed some recirculation in the bay, suggesting, that once the plume has moved into the bay it can stay there trapped in an eddy.

The survey found that if the concentration of Faecal Coliforms in storm water, spilling from Inchcape Short Outfall is assumed to be 2 x 10^6 Faecal Coliforms /100ml and minimum dilution achieved by the plume is 3.4E-6, then the concentration at the sampling point could be $2x10^6$ * 3.4 E^{-6} = 6.8 FC/100 ml. This is below the guideline BW standard. If the minimum dilution of the boat sample is used, the plume with a concentration of $2x10^6$ * 4.5 E-5 = 900 FC/100 ml and fails the guideline bathing water standard only 200m from the shore. If a storm overflow spill was of significant duration, continuously spilling for hours, the high bacteriological background concentration could quickly build up as a result of dilution with the waters, so any subsequent dilution with clean seawater will be less. The eddying of the plume in the bay would amplify this effect.

In September 2003, SEPA operatives carried out a drogue test in the sea adjacent to the bathing water. This was to establish if local currents could potentially move sewage discharged from the Inchcape Short and Long outfalls into the bathing water and thus degrade the water quality. Figure 24 shows results of the test.

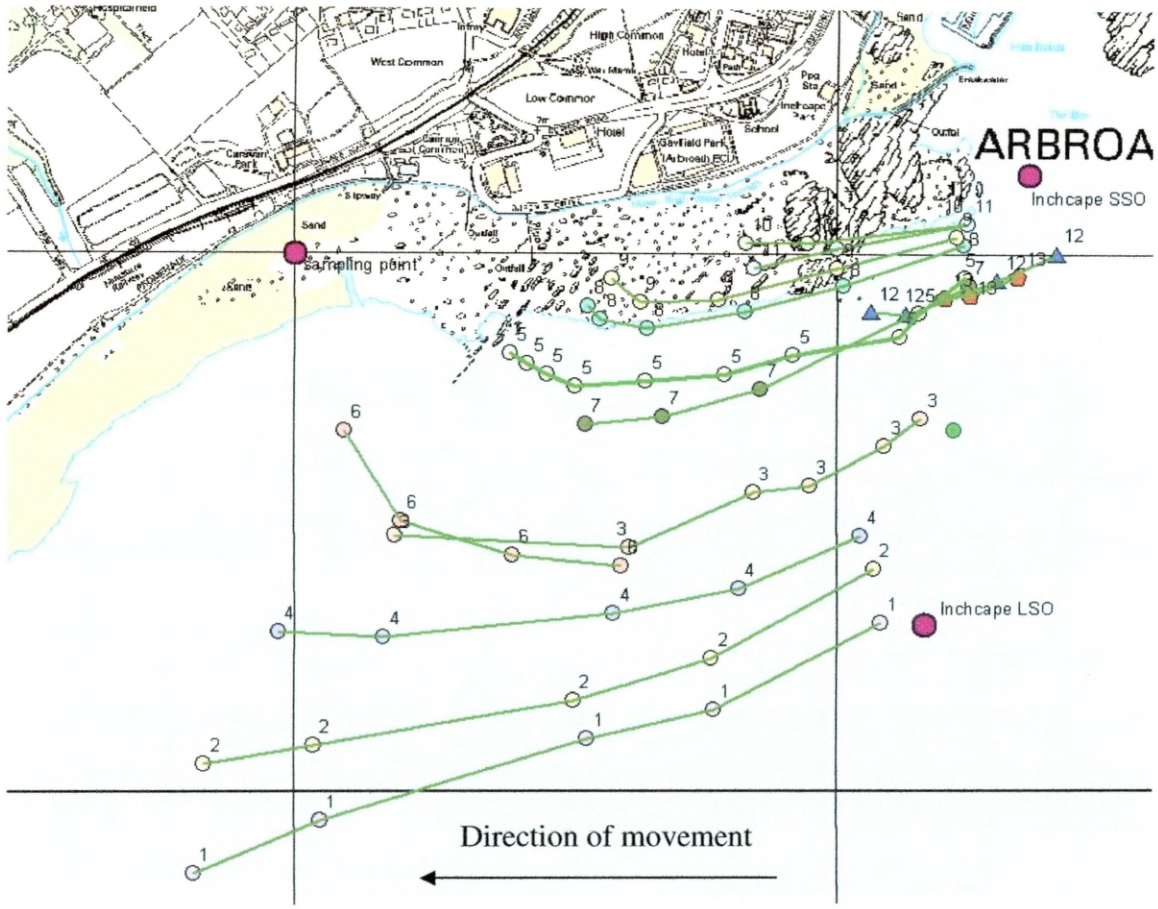

Figure 24 – Drogue studies showing potential for near shore currents to move sewage from sewage outfalls towards the Arbroath bathing water (SEPA, 2004a)

Each of the numbers in Figure 24 represents an individual drogue and their movement from east to west in the water body over 3 hours. The test found that discharges from the Inchcape Long Outfall are likely to spread parallel to the coastline while discharges from the Inchcape Short Outfall are swept onto the Bathing Water sampling point with recirculation in the area likely to allow accumulation of faecal indicator organisms. SEPA concluded that the major influence on compliance with the Bathing Standards at West Links sampling point, Arbroath was the Inchcape Short Outfall (SEPA, 2004a)

Summary

To summarise, the main impact to bathing water quality at Arbroath is the Inchcape short outfall. Studies of the Elliot and Brothock Waters showed that point source sewage rather than diffuse agricultural run-off was the greatest source of faecal pollution. Yet due to geomorphological considerations such as the sand bar present at the end of Elliot Water, the potential impact of this is much reduced.

The work described helps to define the catchment characteristics and the stressors that can impact on the bathing water. This provides a level of micro scale detail that may not be provided in the Water Framework Directive requirements as discussed earlier in Chapter 2. The WFD uses a macro scale approach to these issues. The information gained from the various studies shows how the Arbroath bathing water is impacted. This could act as an example to competent authorities to both the range of inputs that need to be considered and the types of strategic approaches that could be used to drive best practice in the development of bathing water profiles as required in Article 6 in the revised Directive.

In line with Article 6 and Annex III of the Directive, an accompanying map was created that shows where the primary sources of the pollutants affecting the bathing water are located. The map can be found along with the actual Bathing Water Profile in Appendix 4.

5.3.1.2 Article 7 - Water Quality Data

As stated in COM 581, there is a need for a full understanding of the pollutants that could potentially affect bathing waters. This information helps to form the Bathing Water Profile as described in Annex III of the Directive. The profile drives many other aspects of the Directive. Pollutant entrainment and effects on bathing waters need to be fully understood if integration with the WFD is to be achieved. It was decided that work on ecological monitoring of Bathing Waters was important to overall water quality. Even though it is not explicitly mentioned in the Articles of COM 581, this is another case of following the ethos of the Directive and the large change in policy and legislation that has led to it and the WFD. In this section, biomonitoring data recorded as part of the Framework trial in the summer of 2005 are highlighted. Information on the literature review, multi-criteria analysis, protocols and pilot testing that led to the chosen biomonitoring techniques was presented in Chapter 3.

Methods

Flexible frame biomonitoring cages, as developed and verified in the pilot study in the summer of 2004 (Chapter 3, Section 4.2), were deployed at three locations in the Arbroath inter-tidal zone as shown in Figure 25. The three locations were chosen after collaboration on a SEPA research project (SEPA, 2004a) and previous work (Staines, et al., 2003) showed where the areas under greatest potential stress from pollutants both from point and diffuse sources were. These three sampling stations were called AB1, AB2 and AB3 and corresponded to the designate EC bathing water in Arbroath, the harbour and Victoria Sands recreational water, respectively. Within each of these three locations four cages were deployed to minimise risk of test organism loss due to vandalism and severe meteorological conditions.

Figure 25 - Research Sampling Stations

AB1 was the actual bathing water sampling point. AB2 was located in the harbour where a predominant number of stressors occur from both point source pollution related to the fishing industry and sewage outfalls and also any surface runoff that may enter the water

here. AB3 was sited at Victoria sands and chosen as a control as there are no direct sewage outfalls near the sampling station and no river outlets.

Results

Mussels were tested for Growth, Respiration and Neutral Red Retention in accordance with protocols in Chapter 3. Two cycles of sampling were carried out with 8 sampling days within each 28 day cycle. Cycle 1 was carried out from 9th August 2005 until the 6th September 2005. Cycle 2 was carried out from 10th September 2005 until 6th October 2005.

For each sample, ten mussels were collected per sampling station as detailed in Chapter 3, with the subsequent data from five organisms used to create an average which was then plotted on a graph. The graphs and tables below (Figures 26-31; Tables 19-24) therefore display for each method a result from an average of five mussels collected at each sampling station and the control as established in earlier testing (Chapter 3). The graphs are supported by the averages as discussed and the highlighting of any abnormal ambient conditions recorded. Error bars represent the standard deviation of the data used for the averages. The complete raw dataset is presented in Appendix 5.

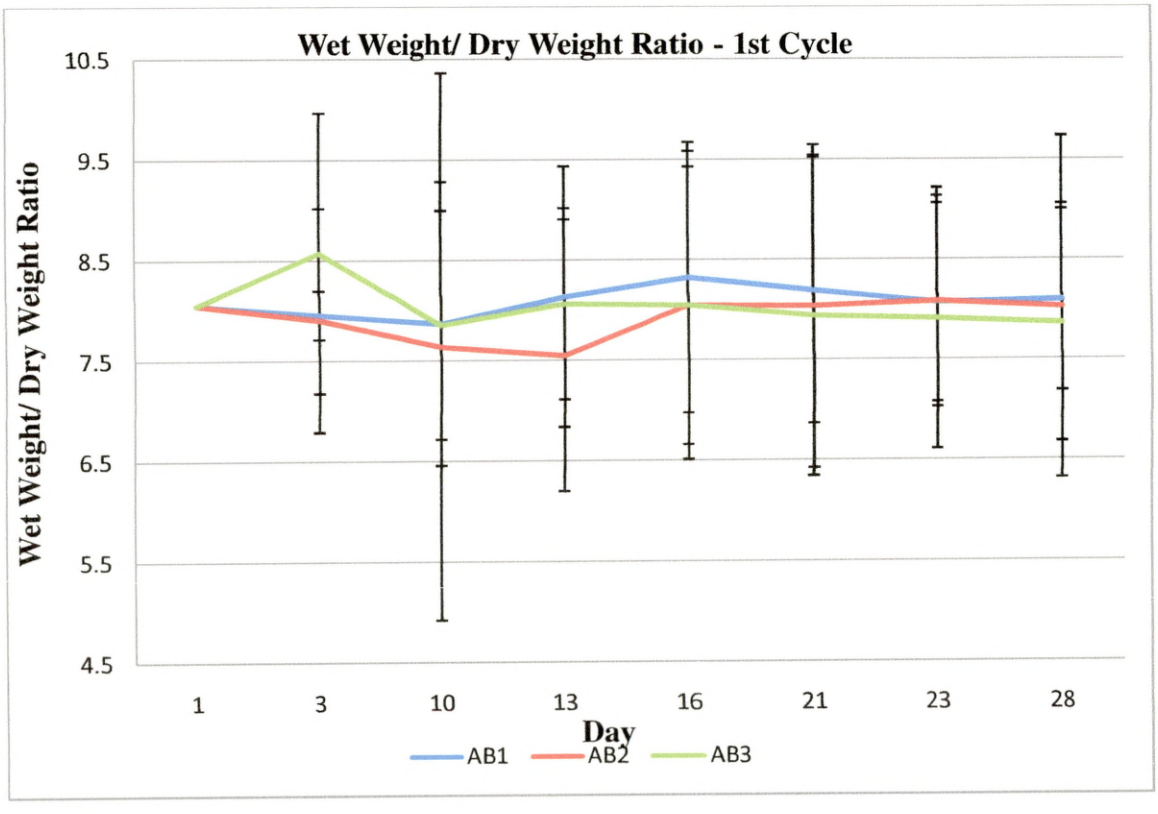

Figure 26 – Wet Weight/ Dry Weight Ratio - Cycle 1

Table 19 - Data averages for wet weight/dry weight cycle 1

Wet Weight/ Dry Weight Ratio								
Location	Day							
	1	3	10	13	16	21	23	28
AB1	8.05	7.96	7.87	8.13	8.32	8.19	8.07	8.09
AB2	8.05	7.90	7.64	7.55	8.04	8.03	8.08	8.02
AB3	8.05	8.57	7.85	8.06	8.05	7.94	7.91	7.86

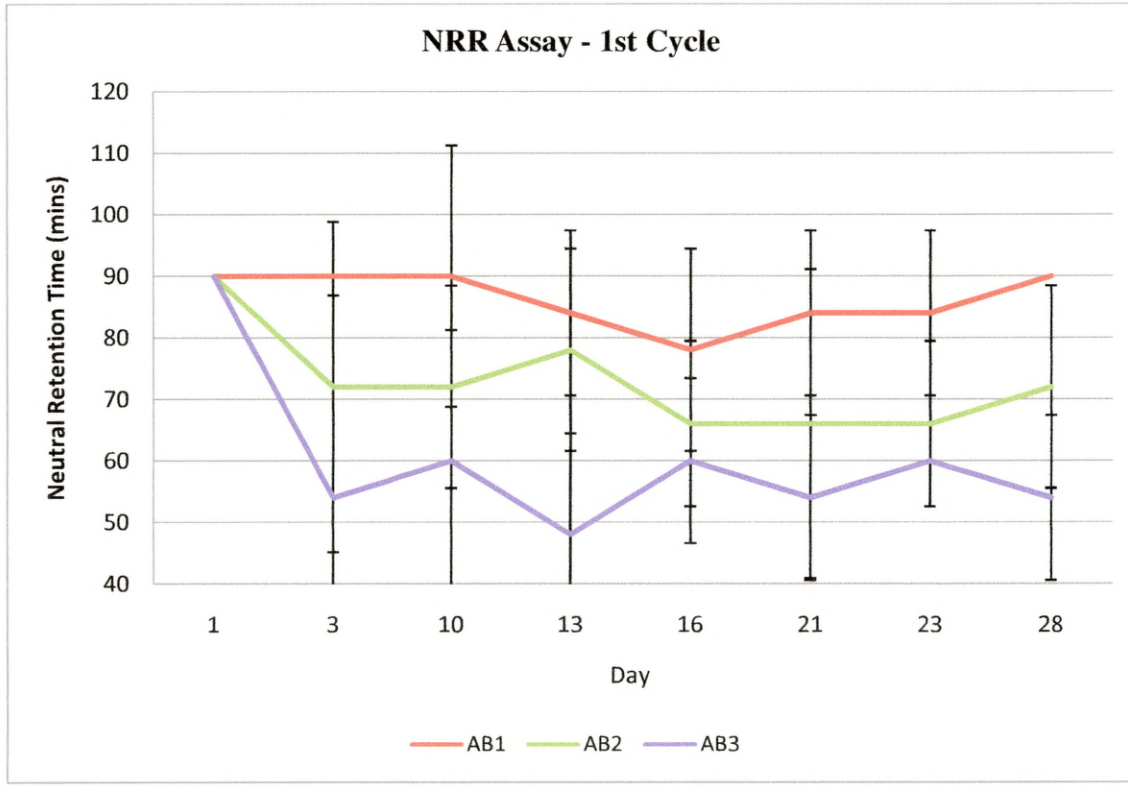

Figure 27 - NRR Assay Cycle 1

Table 20- Data averages for NRR assay - Cycle 1

NRR Assay								
Location	Day							
	1	3	10	13	16	21	23	28
AB1	90	90	90	84	78	84	84	90
AB2	90	72	72	78	66	66	66	72
AB3	90	54	60	48	60	54	60	54

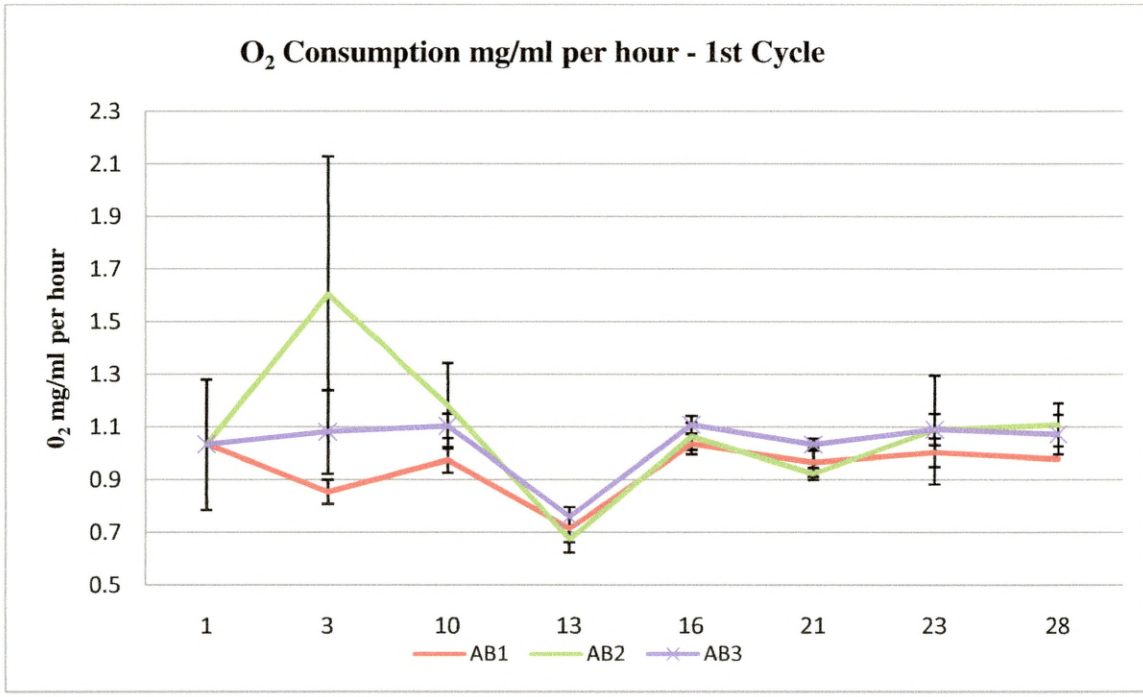

Figure 28 - O_2 Consumption - Cycle 1

Table 21 - Data averages for O_2 Consumption -cycle 1

O_2 Consumption								
Location	Day							
	1	3	10	13	16	21	23	28
AB1	1.03	0.86	0.98	0.72	1.03	0.97	1.00	0.98
AB2	1.03	1.60	1.18	0.68	1.06	0.92	1.09	1.11
AB3	1.03	1.08	1.10	0.76	1.11	1.03	1.09	1.07

From the data for the first cycle it can be seen that on Day 13 of sampling there appears to be degradation or stress occurring to the test organisms. This can be seen with Oxygen consumption and also a steep drop in the Wet Weight/ Dry weight ratio at AB2. This correlated with an increased microbiological reading by SEPA the next day. This could mean that there was pollutant loading entering the harbour area. However, there is also variation over other days that may not be able to be correlated with pollution, which cast doubts on the validity of the methods.

From the second cycle it can be seen in all assays, days 10 and 13 show large reactions. On these days there was sewage derived litter and signs of storm damage at the sampling points. These could be interpreted as pollutants entering the waterbody.

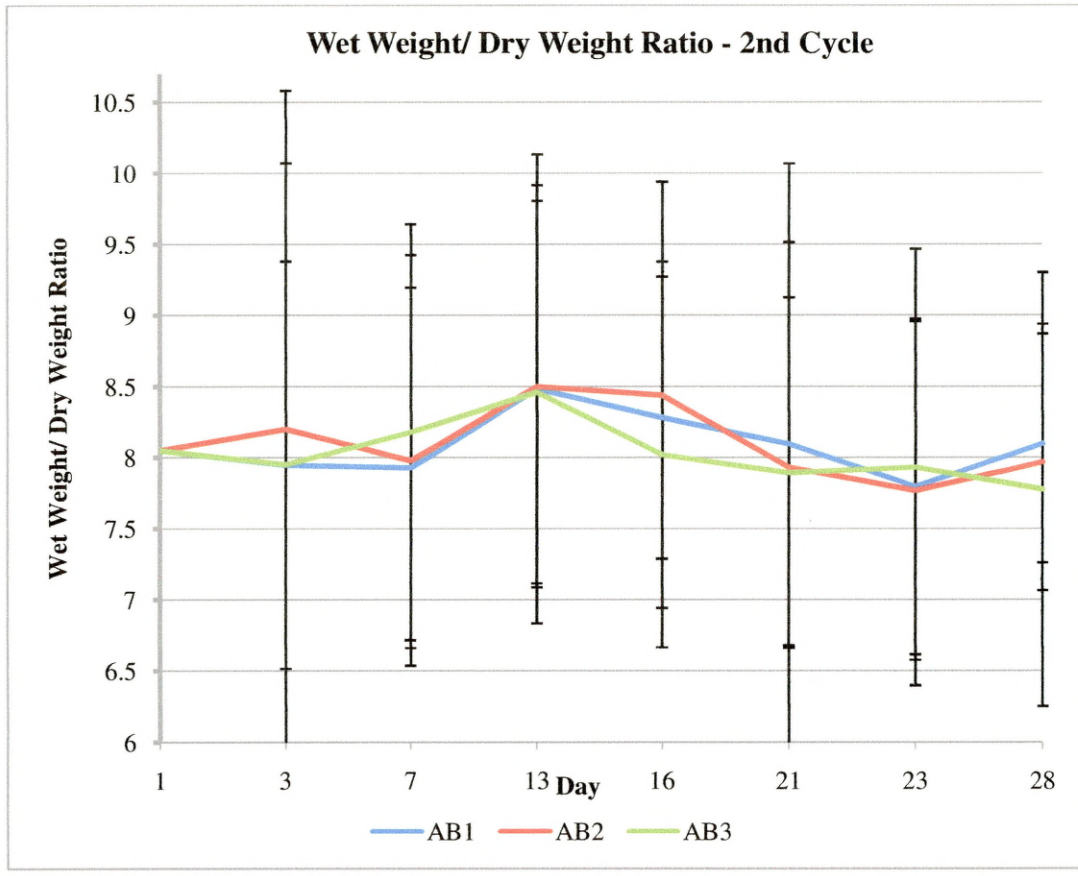

Figure 29 - Wet Weight/ Dry Weight Ratio - 2nd Cycle

Table 22 - Data average for Wet Weight/Dry Weight ratio - 2nd Cycle

Wet weight/Dry Weight Ratio								
Location	Day							
	1	3	7	10	13	21	23	28
AB1	8.05	7.95	7.93	8.48	8.28	8.10	7.79	8.10
AB2	8.05	8.20	7.98	8.50	8.44	7.93	7.77	7.97
AB3	8.05	7.95	8.18	8.46	8.02	7.89	7.93	7.78

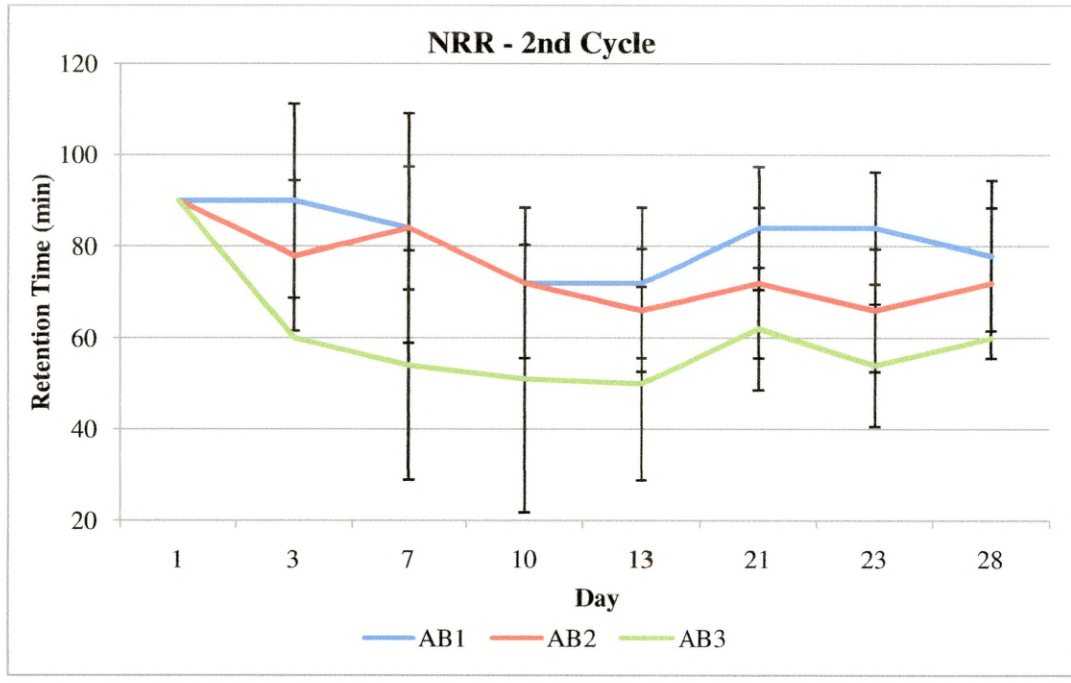

Figure 30 - NRR - 2nd Cycle

Table 23 - Data averages NRR - 2nd Cycle

NRR Assay								
Location	Day							
	1	3	7	10	13	21	23	28
AB1	90	90	84	72	72	84	84	78
AB2	90	78	84	72	66	72	66	72
AB3	90	60	54	51	50	62	54	60

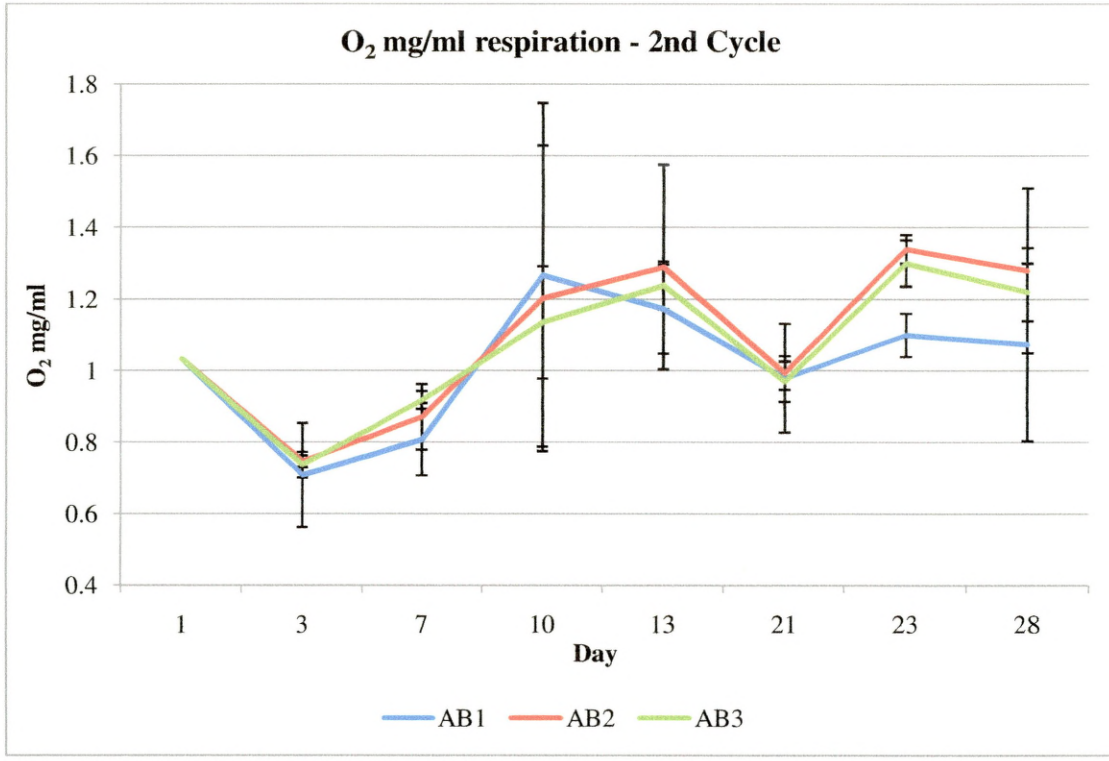

Figure 31 - O_2 consumption - 2nd Cycle

Table 24 - Data averages O_2 Consumption - 2nd Cycle

O_2 Consumption								
Location	Day							
	1	3	7	10	13	21	23	28
AB1	1.03	0.71	0.81	1.27	1.17	0.98	1.10	1.07
AB2	1.03	0.75	0.87	1.20	1.29	0.99	1.34	1.28
AB3	1.03	0.74	0.92	1.14	1.24	0.97	1.30	1.22

Summary

From the data it can be seen that there are some linkages that could be extrapolated, however on the whole the data are not particularly clear. Where a scientific assessment of methods and a review of the literature highlighted that the chosen methods should be suitable for biomonitoring for bathing waters, the results show that this may not be the case.

The error bars on the graphs show that of the three methods, respiration is the most robust in its level of standard deviation. With more testing, respiration could fit well within a regulatory framework, due to its ease of use, rapid results and relatively cheap cost. It is also at the highest level of biological organisation, utilising the whole organism and as such is ecologically relevant. Neutral Red Retention was the second most robust assay; however, the deviation of data was severe and more work would need to be carried out to develop it effectively. The Wet Weight/Dry Weight Ratio was disappointing and the data had large deviations, rendering interpretation invalid for ecological status of bathing waters.

However, the methods may indeed be useful but within interdisciplinary working the overall sum is at the fore and this poses issues with regard to timescales. Work is limited to tight timescales to make sure that it is completed. If more time was available to conduct thorough mono-disciplinary biomonitoring work then more time could have been put towards the overall development and trialling of biomonitoring methods. This is an unfortunate side effect of interdisciplinary research, but is a key output from this research and needs to be discussed further.

5.3.1.3 Article 7 – Monitoring Calendar

This deliverable was linked with the monitoring and as such the calendar was directly created from the monitoring schedule, this was placed on the portal at the beginning of framework testing in the summer of 2005.

5.3.1.4 Article 16 – Non- Technical Summary

This was drawn from the more detailed Bathing Water Profile located in Appendix 4 and was placed onto the portal, detailing the OS co-ordinates of the bathing water, the status of the bathing water and the competent authority responsible for monitoring it.

LINK: http://development.abertay.ac.uk/bwrg/index.htm. This can also be found on a CD-ROM in a pocket attached to the rear of the thesis.

5.3.1.5 Article 16 – Pollution Incident History

The final requirement was collated using networks within SEPA and United Utilities PLC, who supplied all data of spills including date, time, and volume of spill. This was reported on the portal as it occurred and helped to provide causal links when assessing the biomonitoring tools.

The incident history of Inchcape Short Outfall is shown in Table 25. These data would not be available without the prior networks of stakeholders established, a key issue not realised in COM 581.

Table 25- Recorded spills at the Inchcape Short Outfall

Location Name	Month	Start Time	Finish Time	Volume Spilled (m^3)
Inchcape	Jul	06/07/2005 08:48	06/07/2005 14:10	10280.64
Inchcape	Jul	29/07/2005 09:05	29/07/2005 10:39	3682.98
Inchcape	Aug	09/08/2005 16:56	09/08/2005 21:01	8823.12
Inchcape	Aug	24/08/2005 05:01	24/08/2005 05:41	1028.58
Inchcape	Sep	23/09/2005 09:10	23/09/2005 10:31	3625.14

5.3.1.6 Summary of Components

It can be seen from the previous sections that the most effective way of delivering the required articles within the Directive is to use a concerted approach. Many of the requirements are inter-related and need to be co-ordinated, such as in the framework proposed in this research.

To fully understand if the Bathing Water Management Framework (BWMF) has engaged in the underlying principles of the Directive it is important not only to measure just the individual components as described above, but how the total homologue operates and if it

promotes information and communication to the public; to fulfil the needs of the Directive in its entirety.

5.3.2 Assessment of the Portal and the delivery of information goals

As stated earlier in this chapter, the BWMF should be easily accessible to competent authorities for the use in the implementation of the revised Bathing Water Directive. As such it should be an easy to use portal, such as a website, as was highlighted in the literature review in Chapter 4. The portal as such is the practical realisation of the conceptualisation e.g. the Framework as discussed earlier in this chapter and also forms a critical part of the 'toolbox' of methods that have been generated by the Framework. To assess how successful the portal is and thus the communication aspect of the toolbox of methods, the constructed website as technically detailed in Appendix 2 had tracking software installed and is outlined briefly in the following method, along with basic aspects of the website.

5.3.2.1 Methods

To summarise the portal framework construction, a more detailed version of which can be found in Appendix 2, the website was constructed using Dreamweaver MX 2004, using Cascading Style Sheets (CSS) which aid the accessibility of the website to impaired users and fulfil the requirements of the W3C, this allows maximum accessibility by all users, which is crucial to the ongoing ethos of the European Union and specifically COM 581.(EC, 2002). The site was hosted on a University of Abertay Dundee server at the following address: http://development.abertay.ac.uk/bwrg/index.htm and was officially launched on the 12th July 2005. The website can also be found on a CD-ROM in a pocket attached to the rear of the thesis.

Due to the 'live' research status of this website and the information contained within, a one page disclaimer was presented as the first page to users, stating that the research is ongoing is not yet verified and as such users should consult the relevant authorities for confirmed data. This was requested by funding partners and the Law School at the University of Abertay Dundee was consulted in its creation. This also contained details of relevant copyright laws, which was useful as the research was not yet compiled in a thesis or paper.

Constructing and successfully launching a portal was a major outcome as defined in the aims and objectives of this research however it is different to disseminate than actually communicating to stakeholders. Several systems were employed to promote and monitor the usage of the portal. Research from Staines (2002) showed that 58.4% of beach users do not use available competent authorities' information when addressing beach choice. The

same study showed that there was little regard for specific scientific information which was bottom of eight different reasons for visiting a beach.

To monitor how many users accessed the portal, it was decided to use STATCOUNTER™ an internet based website traffic analysis system. Hyper Text Markup Language (HTML) code is inserted on every page of a website and this code sends a package of data whenever a page is visited by a user/stakeholder to the STATCOUNTER™ website containing information on:

- user's Location (Country/State/City);
- user's computer type and specification;
- what pages they have accessed on the site and in what order;
- how they arrived at the website e.g. search engine and keywords used;
- what type of internet browser they use e.g. Microsoft Internet Explorer™.

The dataset is then assimilated by STATCOUNTER™ and can be used to generate a range of information which was also used as a system of feedback to enhance the portal. For this research the main data of interest were the number of users accessing the portal, the number of pages they visited and how many of them re-used the site. These data show if the portal has been used, has not just been stumbled upon by mistake and if the users found it useful enough to return. The results of this can be found in 5.3.2.2. These data were also compared with data collected by SEPA which is the Competent Authority for Bathing Waters in Scotland.

In line with the recommendations of the literature review in Chapter 4, radio and press journalists were contacted about the research. This was seen as a way of highlighting the research and increasing awareness and usage of the portal in a cost-efficient way. In Staines (2002) 75.1% of all respondents (*n= 461*) thought that beaches and related information were not well advertised to the public, which is an extremely large gap in communication. The story which was distributed to a large network of press organisations was picked up by The Arbroath Herald which is the leading local newspaper for the Arbroath area where the research is focused, Tay FM a prominent Radio station in the

Tayside area, A UK/German scientific innovation website and the Guardian national newspaper which ran a feature in its Saturday edition.

The website was also actively promoted through various stakeholders in the UK and abroad and also on various websites relating to beach management and beach usage.

5.3.2.2 Results

The portal which is still hosted and running has currently attracted over 1500 users from over 30 countries since its launch in July 2005, however the data relates to the period of 12th July to 17th October 2005 which was when the portal was subjected to testing within the whole framework. This time period is in line with the bathing water season in Scotland and is comparable to SEPA monitoring. The data is presented in graphical form in Figure 32. The complete raw dataset is presented in Appendix 6.

Figure 32 shows the number of users per day over the defined time period. There were 255 users over 98 days, which is the equivalent of 2.60 users per day to the portal. The highest number of users on one day was 29 on the 20th September which was shortly after the first press releases and represents in excess of 1000% of normal daily usage. The second largest number of users per day was on the 28th September with 17 users on one day; this was after a second wave of press releases.

There were days when there were no visitors to the portal, predominantly on the weekend. Over the time period the 255 users generated 2066 hits (the numbers of individual pages viewed), which is the equivalent of 8.23 pages per user on average, however the most pages viewed on one day was 202 by only 5 users on the 19th July, soon after the portal's launch. This means users were repeatedly viewing various pages.

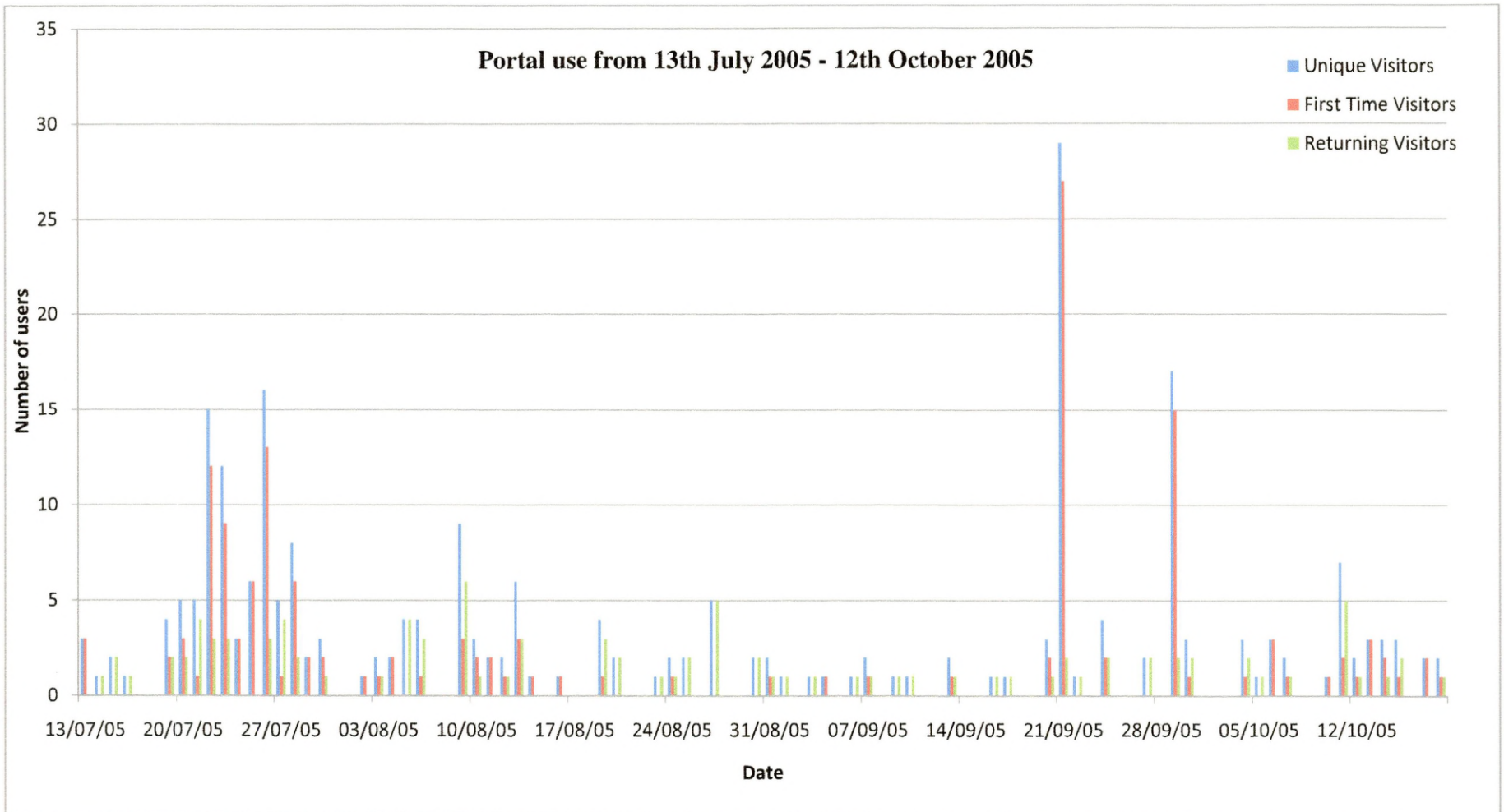

Figure 32 - Graph showing users per day (July to October 2005)

Of the 255 users, 156 users re-visited the portal which represents 61% retention of all users. When compared to how many users accessed the SEPA website on bathing waters normalised for one bathing water, e.g. all users accessing their bathing waters site over the time period divided by 110 which is the number of bathing waters and other monitored beaches in Scotland, the research portal had 2.8 times as many users. SEPA had 91 users accessing their site per bathing water (SEPA, 2005).

The active promotion of the portal on the Internet and through other means resulted in the portal being ranked the number one Google™ result for the keyword search 'BATHING and WATERS and RESEARCH' in the world. The Google™ search engine ranks websites on the relevancy, the number of hits related to time and the number of other websites that link to the site.

The amount of traffic shows that the communication strategy was successful and that the framework was used.

5.3.2.3 Conclusions

From the evaluation of the portal framework it is evident that the approach has been successful in completing the aims and objectives of the research stated in Chapter 1. This also shows that interdisciplinary research should be considered when addressing research problems with cross-cutting issues. This evaluation and the research should be of help to SEPA and other competent authorities by showing how a number of approaches and methods to the revised Directive can work. This pilot of the revised Directive in effect shows what needs to be considered. This research and related works will ensure that the revised Directive is implemented both effectively and timely which both have been recurring issues with the implementation of European directives by member states.

Conclusions from this chapter are that, regarding information and its dissemination, competent authorities need to promote their sites and tools more than at present. The research portal began operation only on the 12th July 2005; however 2.8 times as many people viewed it for information relating to bathing waters than the well established SEPA bathing water website that has been reporting for over 5 years. This disparity can be explained by the use of an effective communication strategy for the portal.

When addressing Bathing Water Profiles there needs to be a fully co-ordinated approach as was used in this research. This enabled the delivery of a highly detailed BWP of pollutant inputs and impacts. Competent authorities need to realise that relying on data used as part of the WFD may not be enough, due to the microscale/macroscale argument as discussed in Chapter Two.

Feedback from both US and UK stakeholders showed that this approach was desirable to them and for the work at hand. The Framework demonstrates the potential of interdisciplinary approach.

CHAPTER SIX - CONCLUSIONS

6.1 INTRODUCTION

The conclusions are presented in the following manner. Firstly a critical review of the extent to which the objectives had been fulfilled. The results of this review are presented in Sections 6.2, 6.3, 6.4, 6.5 and 6.6 which allow conclusions to be drawn on the extent to which the interdisciplinary approach has worked, in 6.7. Secondary conclusions are then presented in 6.8 and recommendations for future work which follow this were developed in response to any limitations of the current study that had been identified. These are presented Section 6.9

The overall aim of this research was to assess the legislative and managerial development of the Bathing Water Directive proposal COM 581 and to develop methods and approaches to support this, through the production of a Bathing Water Management Framework (BWMF). The following objectives were established to:

- Review and develop understanding of new legislation and management practices associated with COM 581 and the effects on competent authorities and local authorities;
- Review current knowledge of lower order organismal biomarkers and associated methodologies, to identify the most suitable to test for use in support of COM 581 and verify the effectiveness of the biomarker systems using methodologies identified;
- Review current communication technologies, and research to develop the most appropriate technology that would be capable of effectively disseminating information to the public;
- Address the issues that have arisen from the legislation review, and to determine appropriate bathing water management practices;
- Create the BWMF, testing the system with controlled societal groups, before release into the public domain for 'live' testing, during a bathing water season.

6.2 REVIEW OF NEW LEGISLATION AND MANAGEMENT PRACTICES ASSOCIATED WITH COM 581

The work undertaken to fulfil this objective is presented in Chapter 2. This chapter contained a detailed review of the legal framework in European environmental law and demonstrated how this drives other aspects of the research. The review showed that the ethos of environmental law has changed from a scientific pass/fail system to a holistic approach, which appreciates the use of management measures to fulfil water quality objectives. This has serious implications for competent authorities in delivering these measures which were highlighted in the chapter.

The chapter highlighted how European law works in two ways; the form and the substance. Whereby the text of the Directive instructs the competent authorities of what is required it does not give details of how to achieve these requirements. Understanding how to satisfy these requirements needs an understanding of the substance of the law and where this has come from. This chapter also crucially established the interdisciplinary requirements needed to instigate the revised Directive, namely enhanced biological monitoring and further developed communications.

It can be concluded that the first project objective has been fully achieved. The law review in Chapter 2 established how European environmental law has changed greatly with a key shift towards holistic management of water quality. This chapter also outlined the requirements of the revised Directive and what this means for competent authorities.

It also showed that interdisciplinary research is required to fulfil these requirements.

6.3 REVIEW OF LOWER ORDER ORGANISMAL BIOMARKERS AND SUITABILITY FOR SUPPORT OF COM 581

The work undertaken to fulfil this objective can be seen in chapter three, with subsequent testing in Chapter 5. Chapter 3 showed that there was large numbers of biomarkers available, however there were not many scientific papers dedicated to fitting particular methods into a regulatory regime. This means that the methods presented are not always useful for practical water quality testing. This has been addressed by institutions such Plymouth University and Ghent University, but is not widely applied.

The multi-criteria analysis identified suitable methods using a scientific basis; the 5Rs and also appreciated the time and money constraints that exist in the regulatory testing. All of the methods deployed were rapid, cheap and fairly easy to conduct. This also meant that they aided communication due to the speed with which the results were available. Unfortunately when testing the methods in Chapter 5 the weakness in the interdisciplinary approach was shown. Where there were some data points that showed promise, there was definite need for more time to develop the methods. This could have been rectified by much larger datasets and longer monitoring periods; however this was not possible with the interdisciplinary approach. The chapter partially achieved the objective that was to research and identify the appropriate methods; however there was just not enough time to verify if these methods were successful. The literature and scientific thought process behind the method selection will aid Competent Authorities in their future choices of monitoring water quality and guide future studies.

6.4 MOST APPROPRIATE COMMUNICATION TECHNOLOGIES

The work undertaken to fulfil the third objective is shown in Chapter 4, with the live testing and subsequent analysis shown in Chapter 5. There were many positive conclusions to be drawn from this work. Where the original objective was to review the most appropriate technology it was quickly shown in the literature that this should not be addressed in isolation. Rather the technology or communication channel should be part of an overall communication strategy. This approach was driven by the law review in chapter two and helped to create a robust communication approach utilising the internet as a primary form of communication. The review showed that the internet was an appropriate technology as it is utilised by a majority of the public (59%) and could be adapted to various users, both in terms of accessibility and also allowing them to get the information they required.

Understanding all aspects of communication namely, the Model, Message, Audience and channels allowed the work to be tailored to the specific requirements of the Directive and the spirit of increased citizen engagement in Europe. This approach also was in line with feedback from both US and UK stakeholders that were surveyed. This shows that there is a need for competent authorities to address the way they communicate to the public and other stakeholders. This is not simply a case of dissemination and the deficit model needs to be re-evaluated by scientists and policy makers. As the review in Chapter 4

demonstrated there is no hypodermic needle approach for getting information to stakeholders.

To conclude, it can be shown that the third objective has been achieved. The success of the communication review and subsequent strategy is demonstrated by the results shown in Chapter 5, which shall be discussed under objective five which addresses the creation and testing of the overall BWMF. These results show that the portal received more visitors than the SEPA website; however in a monodisciplinary study much greater analysis could have been applied to verify the results.

6.5 DETERMINING APPROPRIATE BATHING WATER MANAGEMENT PRACTICES

The work undertaken to fulfil this objective is shown in the form of the legislation outlined in Chapter 2 with the subsequent chapters fulfilling the substance of the Directive. Chapters 3, 4 and 5 highlight once again how important interdisciplinarity is to implementing the Directive. It was shown in Chapter 2 that there are specific requirements to adhere to including the development of the bathing water profiles, information to the public and a monitoring calendar. However, this is the form of the law and it was shown in the other chapters how these were reviewed and created. Chapter 5 and the development of the BWMF is a practical realisation of the bathing water management practices.

Chapter 5 shows that an interdisciplinary strategic approach, rather than several single disciplines working in parallel, can be effective. This is backed up by looking at Californian approaches to bathing waters management. However, when looking at the biomonitoring work in particular it can be seen that there are limitations to working this way, namely the amount of work that can be carried out for each discipline. Gathering effective data from many disciplines is extremely hard and the coordination of this is a discipline itself.

It can be concluded that reviewing the law in Chapter 2 helped to determine the legislative requirements for the bathing water management practices and that subsequent chapters (3 and 4) did help to determine how these practices should be developed and created, with testing in Chapter 5. The US surveys of beach managers and the findings from the UK sponsors also helped to confirm the knowledge gained from the various literature reviews and pilot studies. US beach managers stated that information, the Internet and diffuse

pollution were the most important issues for them. This helps to verify the framework in a number of ways, from the development of the framework into a portal, utilising a communication strategy to the need for holistic management of bathing waters due to the diffuse pollution pressures that are hard to quantify with microbiological parameters alone.

6.6 TESTING OF THE BATHING WATER MANAGEMENT FRAMEWORK

Chapter 5 describes the development and testing of the Bathing Water Management Framework and as such demonstrates the work undertaken for Objective five. This chapter is of course the fulcrum of all the other research inputs. The inputs to fulfilling this framework are shown in Chapters 2, 3 and 4.

Chapter 5 showed that the individual requirements in the Directive were created including the Bathing Water Profiles, pollution incident history and the non-technical summary. This would not have been possible without joint working from several organisations including SEPA, Catchment and the Local Authority, Angus and should be seen as one of the major successes of this research.

The live test of the framework in the summer of 2005 showed that biological monitoring of water data can be gathered and disseminated rapidly to users and in an accessible way. The framework received 2.8 (255 versus 91) times as many users as the equivalent SEPA website in spite of only launching within a short time period compared to the SEPA website which has been running since 1996. This could have been due to the aggressive promotion of the portal but there was not enough time to fully evaluate this. This also does not tell us how useful users found the information or how they utilised it.

The approach to the portal was also supported by the Californian approaches such as the Heal the Bay 'Beach Report Card' which uses a simple, visually appealing webpage to display water quality for various beaches.

To conclude, the Framework was created using an interdisciplinary approach which successfully delivered the requirements of the Directive and aided joint working practices across key stakeholders. However, the interdisciplinary approach, whilst working well as a delivery mechanism, did not always leave sufficient time for detailed evaluation.

6.7 EVALUATION OF THE INTERDISCIPLINARY APPROACH

The research presented in this thesis has shown that interdisciplinary working can provide a dynamic approach. This evidence is provided in the establishment of the framework. There are various benefits and challenges with this type of research as can be seen with the issues related to the biomonitoring. This can be weighed against the notable gains in overall understanding in how best to implement the revised Bathing Water Directive. When compared to a monodisciplinary approach this research has advanced in several disciplines and also created a brand new intellectual space in the form of the framework. Whilst the interdisciplinary outputs are powerful the research also managed to deliver the article requirements of the Directive. Where the biomonitoring results did not produce the most useful data, the fact that the methods were developed within the Framework and with understanding of a regulatory regime at all was a testament to interdisciplinarity.

The major drawback to the research was the lack of time to develop specific areas, with overarching efforts placed towards generating the homologue. The work as such could have benefited from data being collected over several seasons.

6.8 SECONDARY CONCLUSIONS

Further to the primary conclusions, there are several further conclusions that can be drawn. Primarily the message that comes from all areas of the thesis is that there needs to be increased participation by all stakeholders. This was shown in the Californian approach and also by the confused picture of the UK shoreline management approach. To instigate this there should be much more trans-national cooperation, particularly between the EU and US, where many bathing water management systems are developed. This would then put local systems up to global scrutiny and thus make them stronger.

The other conclusion that can be drawn from this work is the engagement with citizens. This simply does not happen, however many initiatives appear to be implemented. With the development of targeted well planned communications the research portal gained almost three times as many users as SEPA. This should not be the case and the Competent Authorities really need to address this problem in the future.

6.9 FUTURE WORK

From the work carried out in this thesis and the conclusions above it can seen that there are several areas where future work can be carried out. These are:

Greater work needs to be carried out in developing ICZM practices; these could be some of the most significant advances in coastal management for the UK and Europe. Enabling established groups such as the Estuary Fora to operate in the same way as the Santa Monica Bay Restoration Commission – Technical Advisory Group (SMBRC – TAG) would allow all stakeholders to drive forward improvements and more importantly break down the barriers that exist between the various stakeholders, which stop effective joint working practices.

There needs to be more work carried out in establishing biomonitoring methods in inter-tidal areas that can be used rapidly and deployed within a regulatory regime. These will become more and more important as water quality objectives progress within Europe.

To increase participation and involvement with all stakeholders, decentralised workshops for people involved in bathing waters management should be carried out. These will allow the development of good practice and increase cohesive action for bathing waters.

For Competent Authorities such as SEPA one of the most important areas they could develop is the use of interdisciplinary working practices and the creation of interdisciplinary teams. As stated previously, requirements of directives are created in individual parts of SEPA and then compiled at the end. This is of course overseen by steering groups who are by their nature multidisciplinary but these groups typically only meet every 3 months and act as a check on progress rather than integrating disciplines. The biggest challenges facing SEPA and other competent authorities such as Climate Change and Energy generation are all interdisciplinary and cannot be tackled with a continuing reliance on monodisciplinary working practices.

CHAPTER SEVEN – REFERENCES

ACUTT, N., ALI, A., BOYD, A., HARTMANN, A., KIM, J., LORENZONI, I., MARTELL, M., PYHALA, A. & WINKELS, A. (2000) An Interdisciplinary Framework for Research on Global Environmental Issues. *Method or Madness? The use and abuse of inter-disciplinary research.* Southampton.

ADAMS, S. M. & GREELEY, M. S. (2000) Ecotoxicological indicators of water quality: using multi-response indicators to assess the health of aquatic ecosystems. *Water, Air, and Soil Pollution,* 123, 103-115.

ADEY, W. H. & LOVELAND, K. (1991) *Dynamic aquaria: building living ecosystems,* New York, Academic Press.

AHD (2004) *the American Heritage Dictionary of the English Language,* New York, Delta.

ANSARI, Z. A. & INGOLE, B. (2002) Effect of an oil spill from M V Sea Transporter on intertidal meiofauna at Goa, India. *Marine Pollution Bulletin,* 44, 396-402.

ASTLEY, K. N., MEIGH, H. C., GLEGG, G. A., BRAVEN, J. & DEPLEDGE, M. H. (1999) Multi-variate Analysis of Biomarker Responses in Mytilus edulis and Carcinus maenas from the Tees Estuary (UK). *Mar. Poll. Bull.,* 39, 145-154.

AUBIN, D. & VARONE, F. (2002) European Water Policy. A path towards an integrated resource management. *EUWARENESS.* Louvain-la-Neuve, Université catholique de Louvain.

AXIAK, V., MICALLEF, D., MUSCAT, J., VELLA, A. & MINTOFF, B. (2003) Imposex as a biomonitoring tool for marine pollution by tributyltin: Some further observations. *Environment International,* 28, 743-749.

BALLANTYNE, B., MARRS, T. C. & SYVERSEN, T. L. M. (1999) *General and applied toxicology,* London, Macmillan Reference.

BELL, M. L. & DAVIS, D. (2001) Reassessment of the lethal London fog of 1952: novel indicators of acute and chronic consequences of acute exposure to air pollution. *Environmental Health Perspectives,* 109, 389-394.

BIER, V. M. (2001) On the state of the art: risk communication to the public. *Reliability Engineering and System Safety,* 71, 139-150.

BLOOR, M. C. & BANK, C. J. (2005) Acute and sub-lethal toxicity of landfill leachate towards two aquatic macro-invertebrates: Demonstrating the remediation potential of air stripping. *Environment International,* 31, 1114-1122.

BODIN, N., BURGEOT, T., STANISIERE, J. Y., BOCQUENE, G., MENARD, D., MINIER, C., BOUTET, I., AMAT, A., CHEREL, Y. & BUDZINSKI, H. (2004) Seasonal variations of a battery of biomarkers and physiological indices for the mussel Mytilus galloprovincialis transplanted into the northwest Mediterranean Sea. *Comparative Biochemistry and Physiology C,* 138, 411-427.

BORENFREUND, E. & PUERNER, J. A. (1985) Toxicity determined in vitro by morphological alterations and neutral red absorption. *Toxicology Letters,* 119-124.

BOURNEMOUTHCOUNCIL (2006) Bournemouth Coastal Management Framework http://www.bournemouth.gov.uk/residents/environment/coastal_management.asp. Bournemouth.

BRENTON, T. (1994) *The greening of Machiavelli: the evolution of international environmental politics*, Earthscan; Royal Institute of International Affairs.

BROWN, R. J., GALLOWAY, T. S., LOWE, D., BROWNE, M. A., DISSANAYAKE, A., JONES, M. B. & DEPLEDGE, M. H. (2004) Differential sensitivity of three marine invertebrates to copper assessed using multiple biomarkers. *Aquatic Toxicology - Amsterdam-,* 66, 267-278.

BRUNS, I., FRIESE, K., MARKERT, B. & KRAUSS, G. J. (1997) The use of Fontinalis antipyretica L. ex Hedw. as a bioindicator for heavy metals. 2. Heavy metal accumulation and physiological reaction of Fontinalis antipyretica L. ex Hedw. in active biomonitoring in the River Elbe. *Science of the Total Environment,* 204, 161-176.

BUIKEMA, A. L., NIEDERLEHNER, B. R. & CAIRNS JR, J. (1982) Biological Monitoring Part IV - Toxicity testing. *Water research,* 16, 239-262.

BURNS, T. W., O'CONNOR, D. J. & STOCKLMAYER, S. M. (2003) Science communication: a contemporary definition. *Public Understanding of Science,* 12, 183-202.

BURTON, G. A. (1999) Realistic assessments of ecotoxicity using traditional and novel approaches. *Aquatic Ecosystem Health and Management,* 2, 1-8.

CALOW, P. (1992) The Three R's Of Ecotoxicology. *Functional Ecology,* 6, 617-619.

CALOW, P. (1993) *HANDBOOK of ecotoxicology,* London, Blackwell Scientific.

CAMUS, L. (2002) Heart rate, respiration and total oxyradical scavenging capacity of the Arctic spider crab, Hyas araneus, following exposure to polycyclic aromatic compounds via sediment and injection. *Aquatic Toxicology,* 61, 1-13.

CAMUS, L., BIRKELY, S. R., JONES, M. B., BORSETH, J. F., GROSVIK, B. E., GULLIKSEN, B., LONNE, O. J., REGOLI, F. & DEPLEDGE, M. H. (2003) Biomarker responses and PAH uptake in Mya truncata following exposure to oil-contaminated sediment in an Arctic fjord (Svalbard). *Science of the Total Environment,* 308, 221-234.

CAREY, J. (1975) A Cultural approach to communication

Communication, 2, pp. 1-22.

CARSON, R. L. (1962) *The silent spring,* New York, Penguin.

CATHARINO, M., VASCONCELLOS, M., DE SOUSA, E., MOREIRA, E. & PEREIRA, C. (2008) Biomonitoring of Hg, Cd, Pb and other elements in coastal regions of Sao Paulo State, Brazil, using the transplanted mussel Perna perna (Linnaeus, 1758). *Journal of Radioanalytical and Nuclear Chemistry,* 278, 547-551.

CHAPMAN, P. M. (1995) Ecotoxicology and Pollution--Key Issues. *Mar. Poll. Bull.,* 31, 167-177.

CHAPMAN, P. M. (2002) Integrating toxicology and ecology: putting the ''eco'' into ecotoxicology. *Mar. Poll. Bull.,* 44, 7-15.

CHENG, H. C. & LAI, R. W. (2003) Use of the proportionality equations for analyses of dose-response curves. *Pharmacological Research,* 47, 163-173.

CLAUSSE, R. (1968) 'The Mass Public at Grips with Mass Communication', *International Social Science Journal,* 20(4), 625–43

CLINCH, P. (1995) *Legal Information: what it is and where to find it*

London, The Association for Information Management.

CLL (2005) Legal Research Tips. *How to do legal research.* Cornell University.

COLLINS, E. L. & ZOCH, L. M. (2001) Targeting the young, the poor, the less educated: thinking beyond traditional media. *Public Relations Review,* 27, 197-212.

CONLAN (2003) What are the costs and benefits? *Beaches and Bathing Waters: Implications for the Revision to the Bathing Water Directive.* SOAS, London, CIWEM.

COR (1994) Committee of the Regions: opinion *Official Journal C* 210, p.0053.

COR (2003) Opinion: 'Proposal for a Directive of the European Parliament and of the Council concerning the Quality of Bathing Water' 10/10/03. Brussels, Committee of the Regions Rapporteur Olivier, A.

CSL/EP (2005) Directive of the European Parliament and of the Council concerning the management of bathing water quality and repealing Directive 76/160/EEC Joint text approved by the Conciliation Committee provided for in Article 251(4) of the EC Treaty. *PE-CONS 3659/05.*

CUP (2005) *Cambridge Advanced Learner's Dictionary*, Cambridge University Press.

DAILIANIS, S., DOMOUHTSIDOU, G. P., RAFTOPOULOU, E., KALOYIANNI, M. & DIMITRIADISB, V. K. (2003) Evaluation of neutral red retention assay, micronucleus test, acetylcholinesterase activity and a signal transduction molecule (cAMP) in tissues of Mytilus galloprovincialis (L.), in pollution monitoring. *Marine Environmental Research,* 56, pp. 443-470.

DEDMAN, M. J. (1996) *The origins and development of the European Union 1945-95: a history of European integration*, Routledge.

DEFRA (2002) Costing of the Revision to the Bathing Water Directive: Phase 3 Studies.

DEFRA (2002a) Sewage Treatment in the UK: UK Implementation of the EC Urban Waste Water Treatment Directive. London.

DEFRA (2006) Report from the United Kingdom: Implementation of (2002/413/EC) Recommendation of the European Parliament and of the Council, of 3 May 2002, concerning the Implementation of Integrated Coastal Zone Management in Europe. IN POLICY, M. A. C. (Ed.) London.

EC (1967) the classification, packaging and labelling of dangerous substances directive 76/548. *OJP,* 196, 234.

EC (1970) Directive on permissible sound level and the exhaust system of motor vehicles. *OJL,* 042, 0016-0020.

EC (1972) Treaty of Accession of the United Kingdom, Ireland and Denmark. *Official Journal L,* 73.

EC (1973) 1st Environmental Action Programme. *Official Journal C,* 112, 0001-0002.

EC (1973a) Council Directive 73/404/EEC on the approximation of the laws of the Member States on detergents. *OJL,* 347, 0051-0052.

EC (1975) Quality of Surface water for Drinking 75/440. *Official Journal L,* 194, p.26.

EC (1976) Bathing Water Directive 76/160. *Official Journal C,* 031, 0001-0007.

EC (1976a) Dangerous Substances Directive 76/464. *Official Journal L,* 031, P.0001-0007.

EC (1982) Directive on Mercury from the Chloalkali industry 82/176. *Official Journal L,* 081, 0029-0034.

EC (1983) Directive on Cadmium 83/513. *Official Journal L,* 291, 0001-0008.

EC (1987) 4th Environmental Action Programme. *Official Journal C,* 328.

EC (1987a) Single European Act. *Official Journal L,* 169, 0020.

EC (1988) Resolution of 28 June 1988 Council asked Commission to submit proposals to improve ecological quality in Community surface waters. *Official Journal C.,* 209, 003.

EC (1990) Council Directive 90/313/EEC on the freedom of access to information on the environment. *Official Journal L,* 158, 0056-0058.

EC (1991) Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment. *Official Journal L,* 135, P. 0040 - 0052.

EC (1991a) Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. *Official Journal L,* 375, P. 0001 - 0008.

EC (1993) Consolidated version of the Treaty of the European Union. *Official Journal C,* 325.

EC (1994) Proposal for a Council Directive concerning the quality of bathing water COM/94/36FINAL - 22/04/1994. *Official Journal C,* 112, p. 0003.

EC (1995) Action program for groundwater and a revision of Council Directive 80/68/EEC. *Official Journal C,* 49, 0001.

EC (1996) Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control. *Official Journal L,* 257, 0026 - 0040.

EC (1997) Treaty of Amsterdam Amending the Treaty on European Union, the Treaties Establishing the European Communities and Related Acts. *Official Journal C,* 340.

EC (1997a) Amended proposal for a Council Directive on the quality of bathing water COM/97/0585 final 10/01/1998. *Official Journal C,* 006, p. 0009.

EC (1998) UN/ECE - Environment for Europe - Aarhus Ministerial Declaration. *Environmental Policy and Law,* 28, 267.

EC (2000) Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000: establishing a framework for Community action in the field of water policy. *Official Journal L,* 327.

EC (2000a) *Communication from the Commission to the European Parliament and the Council: Developing a New Bathing Water Policy COM(2000) 860 final,* Brussels.

EC (2001) EUROBAROMETER 55.2 Europeans, science and technology. Brussels.

EC (2002) COM 581 final proposal for a directive of the European Parliament and of the council concerning the quality of bathing water. *COD,* 2002/0254.

EC (2002a) Treaty of Rome [Consolidated Text]. *Official Journal C,* 325.

EC (2002b) Decision No 1600/2002/EC of the European Parliament and of the Council of 22 July 2002 laying down the Sixth Community Environment Action Programme. *Official Journal L,* 242, 0001-0015.

EC (2004) European Research: A guide to successful communications. Brussels, European Communities.

EC (2005) Communication from the Commission to the European Parliament pursuant to the second subparagraph of Article 251 (2) of the EC Treaty concerning the common position of the Council on the adoption of a European Parliament and Council Directive concerning the quality of bathing waters. *COM(2004) 846 final.* Brussels.

EC (2005a) Opinion of the Commission pursuant to Article 251 (2) third sub-paragraph, point (c) of the EC Treaty, on the European Parliament's amendments to the Council's Common Position regarding the proposal for a Directive of the European Parliament and of the Council concerning the quality of bathing waters amending the proposal of the Commission pursuant to Article 250 (2) of the EC Treaty. *COM/2005/0277 final*

EC (2006) Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC. *Official Journal L,* 64, 0001.

EC (2008) Attitudes of European citizens towards the environment. IN EC (Ed.) *Special Eurobarometer.* Brussels, European Commission.

EC & TSOUKALIS, L. (1983) *The EUROPEAN Community: past, present and future,* Blackwell.

ECJ (1993) Case C -56/90 Commission vs. UK [1993] ECR I-4109.

EEC (1957) Consolidated Version of the Treaty Establishing the European Community. *OJC,* C325.

EEC (1967) B Treaty establishing a Single Council and a Single Commission of the European Communities. *OJC,* 152, 002-018.

EL-AGRAA, A. M. (1998) *The European Union history, institutions, economics and policies,* Prentice Hall.

EL-AGRAA , A. M. (2001) *The European Union economics and policies,* Harlow, Financial Times; Prentice Hall.

ELLIOT, P. (1972) *The Making of a Television Series,* London, Constable.

ELLMAN, G. L., COURTNEY, K. D., ANDRES JR., V. & FEATHERSTONE, R. M. (1961) A new and rapid colorimetric determination of Acetylcholinesterase activity. *Biochemical Pharmacology,* 7, 88-95.

EP (1997) Report on the proposal for a Council Directive concerning the quality of bathing water - tabled legislative report, 1st reading 21/11/1996. *Official Journal C,* 020, p. 0003.

EP (2005) position, 2nd reading regarding Bathing Waters - 10.05.2005. *Official Journal C,* 092, p. 0019-0064.

EPC (2003) Report (co-decision procedure -1st Reading) on the proposal for a European Parliament and Council directive concerning the quality of bathing water (COM(2002) 581 – C5-0508/2002 – 2002/0254(COD)).

ESC (1994) Economic and Social Committee: opinion, report. *Official Journal C,* 393, p. 0005.

ESC (2003) Opinion: on the proposal for a directive of the European Parliament and of the council concerning quality of bathing water (16/9/03). Brussels, European Economic and Social Committee Rapporteur Buffentaut, S.

EU (2001) 1.4.24. Council Conclusions on a new bathing water policy. *EU Bulletin - Environmental Quality and Natural Resources,* 3-2001.

EU (2003) Beginnings: war and peace. *The history of the European Union.* http://europa.eu.int/abc/history/index_en.htm.

EU (2003a) Eurobarometer survey: Europeans see the environment as top priority.

FERNANDEZ, J. A., ABOAL, J. R. & CARBALLEIRA, A. (2004) Identification of pollution sources by means of moss bags. *Ecotoxicology and Environmental Safety.,* 59, 76-83.

GALLOWAY, T. S., BROWN, J. R., BROWNE, M. A., DISSANAYAKE, A., LOWE, D., JONES, M. B. & DEPLEDGE, M. H. (2004a) Ecosystem management bioindicators: the ECOMAN project – a multi-biomarker approach to ecosystem management. *Marine Environmental Research,* 58, 233-237.

GALLOWAY, T. S., BROWNE, R. J., BROWNE, M. A., DISSANAYAKE, A., LOWE, D., JONES, M. B. & DEPLEDGE, M. H. (2004) A multibiomarker approach to environmental assessment. *Environmental Science and Technology,* IN PRESS.

GERBNER, G. (1967) Mass Media and Human Communication Theory. IN FRANK, E. X. (Ed.) *Human Communication Theory: Original Essays.* New York, Rinehart and Winston.

GIORDANI, G., ZALDÍVAR, J. M. & VIAROLI, P. (2009) Simple tools for assessing water quality and trophic status in transitional water ecosystems. *Ecological Indicators,* 9, 982-991.

GOLDSTEIN, A., ARONOW, L. & KALMAN, S. M. (1974) *Principles of Drug Action: The Basis of Pharmacology 2nd Edn,* New York, Wiley.

GOSLING, E. (1992) *The Mussel Mytilus: ecology, physiology, genetics and culture,* Elsevier.

HACKNEY, R., XU, H. & RANCHHOD, A. (2006) Evaluating Web Services: Towards a framework for emergent contexts. *European Journal of Operational Research,* 173, 1161-1174.

HANNAM, M. L., BAMBER, S. D., SUNDT, R. C. & GALLOWAY, T. S. (2009) Immune modulation in the blue mussel Mytilus edulis exposed to North Sea produced water. *Environmental Pollution,* 157, 1939-1944.

HERRICK, J. E., BESTELMEYERA, B. T., ARCHER, S., TUGEL, A. J. & BROWN, J. R. (2006) An integrated framework for science-based arid land management. *Journal of Arid Environments,* 65, 319-335.

HLS (2004) *Using Secondary Sources,* Cambridge, Harvard Law School.

HODGSON, E. & LEVI, P. E. (1997) *A textbook of modern toxicology,* Stamford, Appleton and Lange.

HOL (2003) House of Lords - Revision of the EC Bathing Water Directive. London, The Stationery Office Limited.

HOL (2008) Marine and Coastal Access Bill. *EN.* 2008-09 ed., The Stationery Office Limited.

HOLBORN, G. (2001) *Butterworths Legal Research Guide,* London, LexisNexis.

HONKOOP, P. J., BAYNE, B. L., UNDERWOOD, A. J. & SVENSSON, S. (2003) Appropriate experimental design for transplanting mussels (Mytilus sp.) in analyses of environmental stress: an example in Sydney Harbour (Australia). *Journal of Experimental Marine Biology and Ecology,* 297, 253-268.

HOPKIN, S. P. (Ed.) (1993) *In situ biological monitoring of pollution in terrestrial and aquatic ecosystems.,* London, Blackwell Scientific.

JOWETT, B. (1892) *The Dialogues of Plato, Volume 2 3rd Edition,* Oxford, Oxford University Press.

KARVONEN, E. (1992) Popular Culture and Mastery of Life. *IAMCR Conference.* Brazil, University of Tampere.

KAY, D., ET AL. (1994) Predicting likelihood of gastroenteritis from sea bathing: results from randomise exposure. *The Lancet,* 344, p 905-909.

KAY, D., EDWARDS, A. C., FERRIER, R. C., FRANCIS, C., KAY, C., RUSHBY, L., WAKINS, J., MCDONALD, A. T., WYER, M., CROWTHER, J. & WILKINSON, J. (2003) Does Farmyard Runoff Represent A Significant Source Of Faecal Indicator Organisms For The Bathing Waters Of SW Scotland? *Diffuse Pollution Conference 2003.* Dublin.

KAY, D., STAPLETON, C. M., WYER, M. D., MCDONALD, A. T., CROWTHER, J., PAUL, N., JONES, K., FRANCIS, C., WATKINS, J., WILKINSON, J., HUMPHREY, N., LINF, B., YANG, L., FALCONER, R. A. & GARDNER, S. (2005) Decay of intestinal enterococci concentrations in high-energy estuarine and coastal waters:towards real-time T90 values for modelling faecal indicators in recreational waters. *Water Research,* 39, 655-667.

LASSWELL, H. D. (1948) The Structure and Function of Communication in Society

IN BRYSON, L. (Ed.) *The Communication of Ideas.* New York, Harper.

LATTUCA, L. R. (2001) *Creating interdisciplinarity: interdisciplinary research and teaching among college and university faculty,* Nashville, Vanderbilt University Press.

LEEWORTHY, V. R., EDWARDS, A. C., STONE, E. A., MEADE, N. & PENDLETON, L. (2007) Southern California Beach Recreation Valuation Project. IN LEEWORTH, V. R. (Ed.) Silver Spring, NOAA.

LIONETTO, M. G., CARICATO, R., GIORDANO, M. E., PASCARIELLO, M. F., MARINOSCI, L. & SCHETTINO, T. (2003) Integrated use of biomarkers (acetylcholinesterase and antioxidant enzymes activities) in Mytilus galloprovincialis and Mullus barbatus in an Italian coastal marine area. *Marine Pollution Bulletin,* 46, 324-330.

LISTER, C. (1996) *European Union environmental law: a guide for industry*, Wiley.

LISTON, D. R., NIELSEN, J. A., VILLALOBOS, A., CHAPIN, D., JONES, S. B., HUBBARD, S. T., SHALABY, I. A., RAMIREZ, A., NASON, D. & WHITE, W. F. (2004) Pharmacology of selective acetylcholinesterase inhibitors: implications for use in Alzheimer's disease. *European Journal of Pharmacology,* 486, 9-17.

LOWE, D. M., SOVERCHIA, C. & MOORE, M. N. (1995) Lysosomal membrane responses in the blood and digestive cells of mussels experimentally exposed to fluoranthene. *Aquatic Toxicology -Amsterdam-,* 33, 105.

LYONS, R. A., TEMPLE, J. M. F., EVANS, D., FONE, D. L. & PALMER, S. R. (1999) Acute health effects of the Sea Empress oil spill. *Journal of Epidemiology and Community Health,* 53, 306-310.

MANUSADZIANAS, L., BALKELYTE, L., SADAUSKAS, K., BLINOVA, I., POLLUMAA, L. & KAHRU, A. (2003) Ecotoxicological study of Lithuanian and Estonian wastewaters: selection of the biotests, and correspondence between toxicity and chemical-based indices. *Aquatic Toxicology -Amsterdam-,* 63, 27-41.

MARTINEZ-GOMEZ, C., BENEDICTO, J., CAMPILLO, J. A. & MOORE, M. (2008) Application and evaluation of the neutral red retention (NRR) assay for lysosomal stability in mussel populations along the Iberian Mediterranean coast. *Journal of Environmental Monitoring,* 10, 490-499.

MATTHIESSEN, P. & LAW, R. J. (2002) Contaminants and their effects on estuarine and coastal organisms in the United Kingdom in the late twentieth century. *Environmental Pollution -London Then Barking-,* 120, 739-757.

MCALLISTER , R. (1997) *From EC to EU: an historical and political survey*, Routledge.

MCCARTHY, J. F. & SHUGART, L. R. (1990) *Biomarkers of environmental contamination* London, Lewis.

MCCARTY, L. S. & NUNKITTRICK, K. R. (1996) Environmental biomarkers in aquatic toxicology: fiction, fantasy, or functional? *Human Ecology Risk Assessment,* 2.

MCGLASHAN, D. J., DUCK, R. W. & REID, C. T. (2005) Defining the foreshore: coastal geomorphology and British laws. *Estuarine, Coastal and Shelf Science,* 62, 183-192.

MCLUHAN (1964) *Understanding Media,* New York, Mentor.

MCQUAIL, D. (2000) *McQuail's Mass Communication Theory* London, Sage Publications

MCQUAIL, D. & WINDAHL, S. (1981) *Communication models : for the study of mass communications,* London, Longman.

METCALF&EDDY (2002) *Wastewater engineering : treatment and reuse* London, McGraw-Hill.

MEZHER, T. & TAWIL, W. (1998) Causes of delays in the construction industry. *Engineering Construction and Architecture Management Journal,* 5, 252-260.

MINUTOLI, R., FOSSI, M. C. & GUGLIELMO, L. (2002) Evaluation of acetylcholinesterase activity in several zooplanktonic crustaceans. *Marine Environmental Research,* 54, 799-804.

MITCHELL, G. (2004) The Westley and MacLean (1957) model of communication. *JPEG.*

MORA, P., MICHEL, X. & NARBONNE, J. F. (1999) Cholinesterase activity as potential biomarker in two bivalves. *Environmental Toxicology and Pharmacology,* 7, 253 - 260.

MUSACCHIO, L., OZDENEROLB, E., BRYANT, M. & EVANS, T. (2005) Changing landscapes, changing disciplines: seeking to understand interdisciplinarity in landscape ecological change research. *Landscape and Urban Planning,* 73, 326-338.

NAS (1989) Biological markers in reproductive toxicology. IN MARKERS, C. O. O. B. (Ed.) *Subcommittee on reproductive and neurodevelopment toxicology.* Washington, D.C., National Academy Press.

NEILSEN, J. (1999) *Designing Web Usability : The Practice of Simplicity,* New York, Peachpit Press.

NEWSWEEK (1964) A Life in Nature

Newsweek. New York, Newsweek.

NISSANI, M. (1997) Ten Cheers for Interdisciplinarity: The Case for Interdisciplinary Knowledge and Research. *The Social Science Journal,* 34, 201-216.

O'BRIEN, P., CAREY, J., J., H. & WOERGOETTER, A. (2001) Encouraging environmentally sustainable growth IN Belgium. Paris, OECD.

O'KEEFE, B. (2004) Discussion on Interference with active biomonitoring systems with Brian O'Keefe SEPA. Edinburgh, SEPA.

PAZOS-ROIZ, A. (2004) Biological Responses in Environmental Management: Practical Application, Benefits and Drawbacks. *School of Contemporary Sciences.* Dundee, Abertay.

PEAKALL, D. B. (1994) The role of biomarkers in environmental assessment (1). Introduction. *Ecotoxicology,* 3, 157-160.

POWELL, T. A. (2000) *Web Design: The Complete Reference,* San Francisco, McGraw-Hill.

ROHRMANN, B. (1992) The evaluation of risk communication effectiveness. *Acta Psychologica,* 81, 169-192.

ROSSON, M. B., BALLIN, J. & RODE, J. (2005) Who, What, and How: A Survey of Informal and Professional Web Developers. *Proceedings of the 2005 IEEE Symposium on Visual Languages and Human-Centric Computing.* Dallas, Texas, USA, Computer Society.

ROWAN, K. E. (1991) Goals, obstacles, and strategies in risk communication: a problem-solving approach to improving communication about risks. *Journal of Applied Communication Research,* 19, 300-329.

RTT (2003) Opinion: On the proposal for a directive of the european parliament and of the council concerning the quality of bathing water (COM (2002) 581 - C5-0508/2002-2002/0254(COD)). Brussels, The committee on regional policy, transport and tourism Rapporteur Duin, G.

RUDDOCK, A. (2000) *Understanding audiences : theory and method,* London, SAGE.

SALAZAR, M. & SALAZAR, S. (2000) Standard guide for conducting Field Bioassays with Marine, Estuarine and Freshwater bivalves. *ASTM.*

SCHUURMAN, G. & MARKERT, B. (1998) *ECOTOXICOLOGY ecological fundamentals, chemical exposure, and biological effects*, Wiley; Spektrum.

SE (2004) Aerial Survey of Scottish Beaches, July – September 2003. *Environment Group Research Report.* Edinburgh.

SEPA (1996) Scottish Bathing Waters, 1996, Stirling.

SEPA (2003) Scottish Bathing Waters 2003. Stirling.

SEPA (2004) Scottish Bathing Waters 2004. Stirling.

SEPA (2004a) SEPA Environmental Improvement Plan Final Report. IN MCGOWAN, S. (Ed.) Arbroath, SEPA.

SEPA (2004b) Sampling of Water for Microbiological Analysis. IN SCIENCE (Ed.).

SEPA (2005) Email from Scott Leslie, SEPA webmaster regarding SEPA's bathing waters user counts for the summer of 2005. Stirling, SEPA.

SIU, W. H., CAO, J., JACK, R. W., WU, R. S., RICHARDSON, B. J., XU, L. & LAM, P. K. (2004) Application of the comet and micronucleus assays to the detection of B[a]P genotoxicity in haemocytes of the green-lipped mussel (Perna viridis). *Aquatic Toxicology -Amsterdam-,* 66, 381-392.

SMOLDERS, R., BERVOETS, L., DE COEN, W. & BLUST, R. (2004) Cellular energy allocation in zebra mussels exposed along a pollution gradient: linking cellular effects to higher levels of biological organization. *Environmental Pollution -London Then Barking-,* 129, 99-112.

SMOLDERS, R., BERVOETS, L., WEPENER, V. & BLUST, R. (2003) A Conceptual Framework for Using Mussels as Biomonitors in Whole Effluent Toxicity. *Human and Ecological Risk Assessment,* 9, 741-760.

SNIFFER (1999) Communicating Understanding of Contaminated Land Risks, SNIFFER Project No SN97(11)F.

SORLIN, P. (1994) *Mass Media: Key ideas,* London, Routledge.

SOTO, M., IRELAND, M. P. & MARIGOMEZ, I. (2000) Changes in mussel biometry on exposure to metals: implications in estimation of metal bioavailability in `Mussel-Watch` programmes. *Science of the Total Environment,* 247, 175-187.

STAINES, A. (2001) Ecotoxicology of Marine Invertebrates. *Contemporary Sciences.* Dundee, University of Abertay Dundee.

STAINES, A. (2002) Beach usage: understanding the issues. University of Abertay Dundee.

STAINES, A., BLACKWOOD, D. & STAINES, H. (2003) An Assessment of Microbiological Quality Levels at West Links Bathing Waters, Arbroath. Dundee, Urban Water Technology Centre.

STAPELTON, C., SANDERS, B., KAY, D., ANTHONY, S., LYONS, H., WILSON, J., GREAVES, J., DUNHILL, I., MILES, P. & WITHER, A. (2003) The effects of de-stocking on microbial delivery from catchment diffuse sources in an area affected by Foot and Mouth disease (The Caldew Study). *Diffuse Pollution Conference 2003.* Dublin.

STEINERT, S. A., STREIB-MONTEE, R., LEATHER, J. M. & CHADWICK, D. B. (1998) DNA damage in mussels at sites in San Diego Bay. *Mutation Research,* 399; ISSUE 1, 65-85.

STIRK , P. M. R. & WEIGALL , D. (1992) *The origins and development of the European Community*, Leicester University P.

STURGIS, P. & ALLUM, N. (2004) Science in society: re-evaluating the deficit model of public attitudes. *Public Understanding of Science,* 13, 55-74.

SUKHOTIN, A. A., LAJUS, D. L. & LESIN, P. A. (2003) Influence of age and size on pumping activity and stress resistance in the marine bivalve Mytilus edulis L. *Journal of Experimental Marine Biology and Ecology,* 284, 129-144.

SUNKIN, M., ONG, D. M. & WIGHT, R. (2002) *Sourcebook on environmental law,* London, Cavendish.

TATES, A. D., NEUTEBOOM I., HOFKER M. & L., D. E. (1980) A micronucleus technique for detecting clastogenic effects of mutagens/carcinogens (DEN, DMN) in hepatocytes of rat liver in vivo. *Mutation Research,* 74, 11-20.

TRUHAUT, R. (1977) *Ecotoxicology objectives, principles and perspectives.*

TV-AYE (2006) Commercials: Costs http://www.tvaye.co.uk/commercials.htm.

UK (2005) Internet Access. *National Statistics.* UK Government.

UK (2008) Internet Access. *National Statistics.* UK Government.

UN (1948) Universal Declaration of Human Rights. *Resolution 217A (III).*

UN (1972) Declaration of the United Nations conference on the human environment. Stockholm, UN.

UN (1982) Nairobi Declaration Adopted at the 13th meeting of the session on 18 May 1982.

UNDERWOOD, M. (2004) Cultural.studies http://www.cultsock.ndirect.co.uk/MUHome/cshtml.

UNECE (2005) Aarhus Convention ratified by the European Community. IN WATES, M. J. (Ed.) Geneva, UN ECE.

VALKIRS, A. O., SELIGMAN, P. F., HASLBECK, E. & CASO, J. S. (2003) Measurement of copper release rates from antifouling paint under laboratory and in situ conditions: implications for loading estimation to marine water bodies. *Marine Pollution Bulletin,* 46, 763-779.

VEEN, J. (2001) *The Art & Science of Web Design,* Indiana, New Riders.

VINTEN, A. J. A., SYM, G., AVDIC, K., CRAWFORD, C., DUNCAN, A. & MERRILEES, D. W. (2008) Faecal indicator pollution from a dairy farm in Ayrshire, Scotland: Source apportionment, risk assessment and potential of mitigation measures. *Water Research,* 42, 997-1012.

W3C (2000) Authoring Tool Accessibility Guidelines 1.0 W3C Recommendation 3 February 2000. IN TREVIRANUS, J. (Ed.) Toronto, W3C.

WALKER, C. H. (1996) *Principles of ecotoxicology*, Taylor & Francis.

WATZLAWICK, P., BEAVIN, J. H. & JACKSON, D. D. (1967) *Pragmatics of Human Communication: Study of Interactional Patterns, Pathologies and Paradoxes,* London, W W Norton & Co Ltd

WEDDERBURN, J., MCFADZEN, I., SANGER, R. C., BEESLEY, A., HEATH, C., HORNSBY, M. & LOWE, D. (2000) The Field Application of Cellular and Physiological Biomarkers, in the Mussel Mytilus edulis, in Conjunction with Early Life Stage Bioassays and Adult Histopathology. *Marine Pollution Bulletin,* 40, 257-267.

WELLS, P. E. A. (2001) Rapid Toxicity Assessment and Biomonitoring of Marine Contaminants- Exploiting the potential of Rapid Biomarker Assays and Microscale Toxicity tests. *Mar. Poll. Bull.,* 42**,** 799-804.

WESTLEY, B. H. & MCLEAN, M. S., JR. (1957) A conceptual model for communication research. *Journalism Quarterly,* 34**,** 31-38.

WHO (2001) Water Quality Guidelines, Standards and Health: Assessment of risk and risk management for water-related infectious disease.

WITTIG, R. (Ed.) (1993) *General aspects of Biomonitoring heavy metals by plants,* Weinheim, VCH.

WRIGHT, D. A. & WELBOURN, P. (2002) *Environmental toxicology,* Cambridge, Cambridge University Press.

APPENDIX 1 – MAP OF RESEARCH AREA

Figure 33 shows locations referred to in the research. The left side shows a regional map of the Tayside region, with the image on the right showing an enlarged map of Arbroath and the surrounding catchment. Table 26 provides specific details of the locations.

Table 1 - Key to research locations shown in Figure 33

1. – Arbroath, Angus	2. – Carnoustie, Angus	3. – RAF Leuchars Meteorological station, Fife
4. – East Sands, St. Andrews, Fife	5. – Kingsbarns, Fife	6. - Redford, Angus
7. – Black burn, tributary to Elliot Water	8. – Rottenraw Burn, tributary to Elliot Water	9. – Arbirlot
10. – Elliot Water, entrance to bathing water	11. – Gordies Burn	12. – West Links, SEPA Bathing Water Sampling Point
13. – Inchcape long outfall	14. - Inchcape short outfall	15. – Brothock Water, discharges through Arbroath Harbour
16. – Cliffburn long outfall	17. - Victoria Sands , SEPA Recreational Water Sampling point	18. – Cliffburn short outfall
19. – St. Vigeans	20. – Colliston, location of SEPA rain gauge	21. – Brothock Water
22. – Letham Grange, sewage treatment works	23 – Elliot Water, septic tank outfall	

Figure 1 - Regional and local scale map of research locations

APPENDIX 2 - WEBSITE DESIGN

The Website was designed and built in accordance with Powell (2000) and Nielsen (1999), which are both proponents of good web design. The initial website design was created in accordance with the waterfall model of design as shown in Figure 34. The basic waterfall model logically progresses through each stage needed to design and build effective software specifically in this case a website. Other models of design were not considered

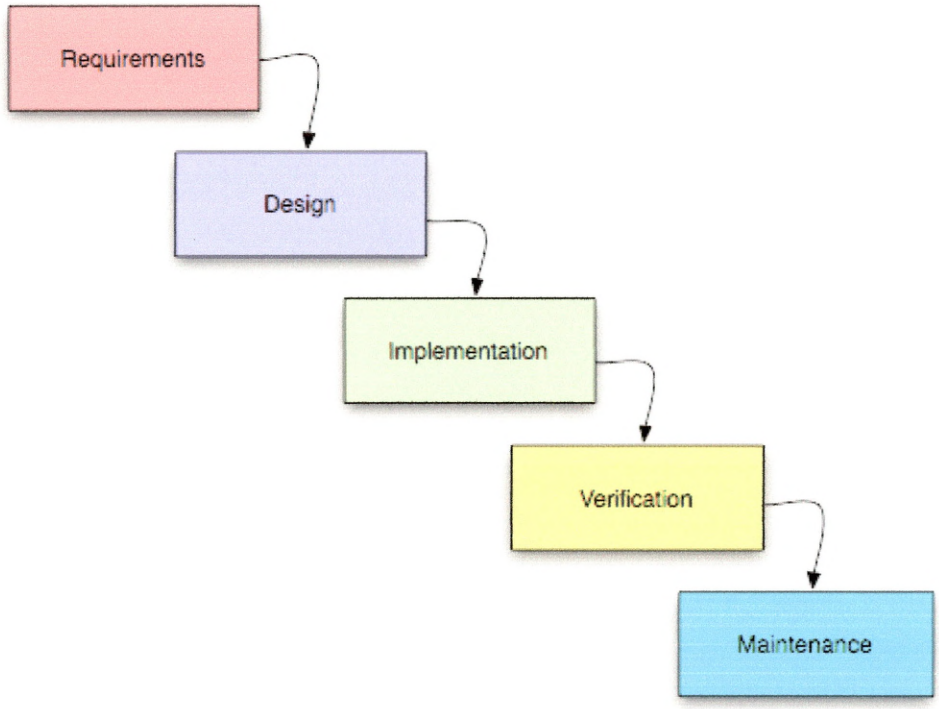

Figure 34 - Waterfall model of web design

Website Requirements / Definition

In all web design it is important to establish the main requirements of the website and to create definite site goals from them. In the research there was a need to adhere to the articles detailed in COM581, so the requirements of the website were straightforward, with a goal "to encompass all required information as detailed in COM581" Please see chapter two for specific details of COM 581 Articles.

The final website consequently was an integrated information portal that allows stakeholders to access information as required under COM581. This includes information and data collected through other aspects of the research e.g. Biological Monitoring (Chapter 3) and legislative directions (Chapter 2).

Table 27 shows the information as required by COM581, by article. This acted as guidance for development of site structure and helps with site navigation, topic organisation and other requirements.

Article	Information Details
Annex III	**Map of Bathing Water with pollution inputs –** as part of the Bathing Water Profile, a detailed map showing sources of point and diffuse pollution, both quantitatively and qualitatively
6	**Bathing Water Profile -** Consisting of information on the bathing water location, pollution sources, a map showing these sources and inputs and a description of monitoring points
7	**Monitoring Calendar - A** list of dates of water quality monitoring, made public at the beginning of a bathing water season
7	**Water Quality Data -** Monitoring water quality as set out in Annex I and other such methods where needed
16	**Non- Technical Summary-** A summary of the overall bathing water. Designation and other pertinent information related in lay terms.
16	**Pollution Incident History -** of incidents, requiring management measures

Table 27 - COM581 Articles and Information Required

With the overall goal and informational needs established the next issue to resolve was the audience. As discussed in chapter 4 everyone is a potential stakeholder in bathing waters, as highlighted by Rohrmann (1992). To satisfy this need the website was designed to maximise accessibility and usability by all members of society who may wish to access it. This was achieved using W3C guidelines. Further details of how this was implemented are discussed in the next section that details the practical building of the website.

With the required informational needs established, the architecture of the site was formulated, which is essential before any actual website creation takes place, due to the technical issues that can arise later on in the build process. Making the site easy to use for the user was paramount. Due to this the decision was made to use Wide Hierarchy web architecture. To recap from Chapter 5 this architecture gives the user a wider set of choices on the front page of the website and then less levels of depth, this is opposed to the Narrow Hierarchy where limited choices are available initially with greater levels of depth further into the site. With a limited set of information requirements, the main disadvantage of the wide hierarchy system becoming too broad in the initial stage was overcome and this meant that site could be built to the 3-click approach whilst making sure the user didn't get confused at the index page.

From the main site index page, information required and otherwise was detailed under four topics/sub-sections with details of included content per sub-section detailed in Table 2. This initial listing was defined as the information needed to fulfil objectives set out in COM581 articles as detailed in Table 26. Table 27 shows how the information was organised by sub-group.

Topic	Information within topic – each page detailed
About this Site	**About this site** – a brief description of the project in lay terms and contact details
Water Quality Data	**Microbiological Data** – as established in BWD 76/160 and still required in COM581, sourced from competent authority (SEPA) **Biological Monitoring** – Research data see chapter 3 for specific details **Methods** – detailed methodologies of methods used, as required under original directive and COM 581
Location Data	**Map Of Location** – Map of designated bathing water Bathing Water Profile Incident History
Official Documents	Non- Technical Summary Monitoring Calendar **COM 581** - full proposal directive

Table 28 - Organisational Structure of Information by topic

These topics were organised using a wide hierarchy and produced the following site layout as detailed in Figure 35.

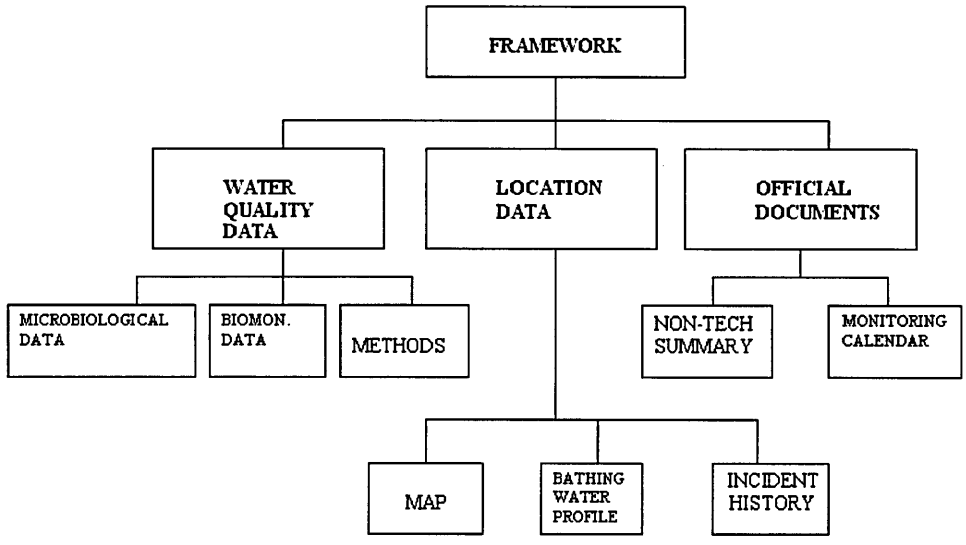

Figure 35 - Site Layout defined by required information

With the layout realised the website moved into the next phase, which is the designing of the webpage prototype template, what each individual webpage will look like.

Webpage Prototype Template

The prototype template is created using defined rules and the design style of the web designer; as such this stage can become protracted due to the designer having to balance between usability and aesthetics. Initially the template was designed on paper, with all required buttons, graphics, navigation and text. It was designed using a standard web browser outline, as shown in Figure 36.

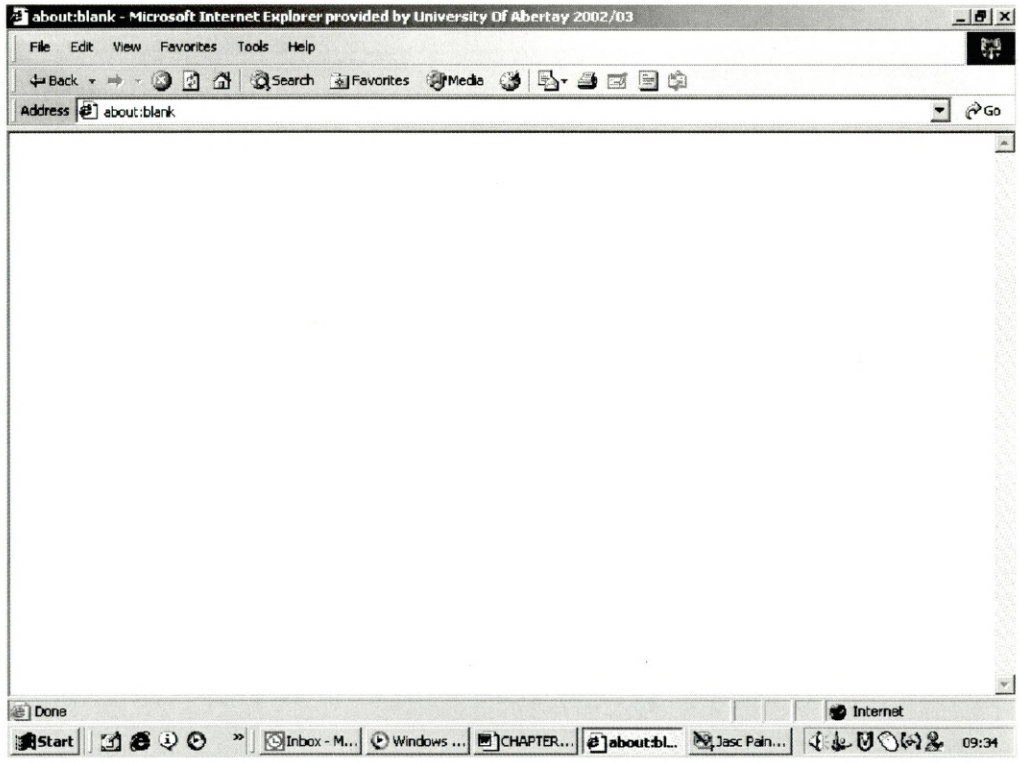

Figure 36 - Typical Web Browser Display

Throughout this section each parameter that needs to be fulfilled to enable effective webpage design shall be detailed in sub-sections.

Page Layout

The first issue to resolve in layout is the resolution or screen size that the webpage will be viewed on. This varies from 310 x 100 pixels in mobile telephones up to 1,600 x 1,200 in high-resolution computers, however the most common screen size is 600 x 800 pixels and so this was used for the webpage design. It should be noted that a standard A4 page of 22x 28 cm is the equivalent of 612 x 792 pixels.

Earlier in this appendix there was discussion on the usability of a website and how this directly affects how a webpage will look. Veen in 'The Art of Science of Web Design' (2001) approaches the issue using the system developed by Keith Instone, whereby every page of a webpage should satisfy 3 questions; Where am I? , What's here? and Where Can I go? If the page does not fulfil all three questions then it is not working properly.

These three questions can be fully realised in a webpage using a simple 3-panel layout (Figure 37).

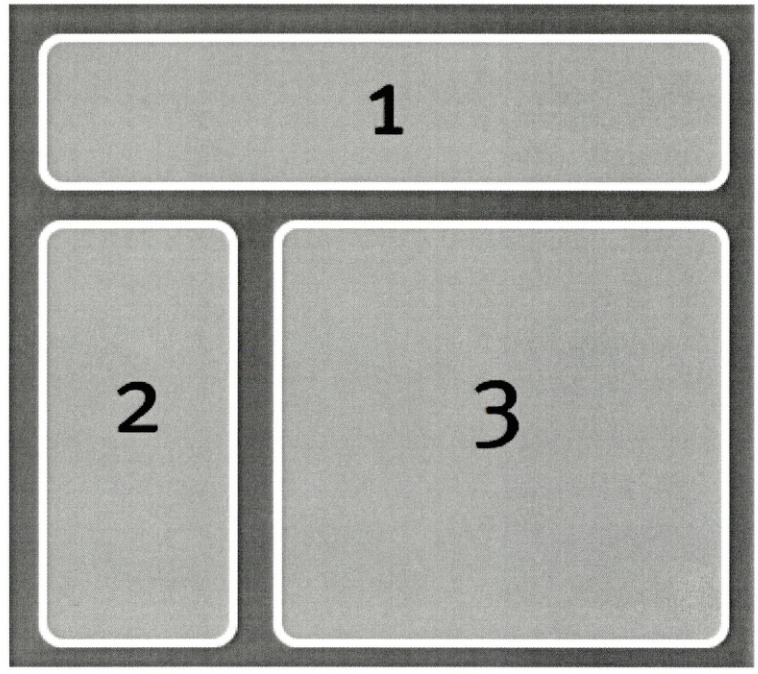

Figure 37 - 3-Panel Layout of web design

Panel 1 fulfils the Where am I question, and will be in the form of a text or graphic with the website name and/or logo. Panel 2 is the main site navigation bar and fulfils where can I go? Navigation technical specification shall be described later. Finally Panel three contains what's here, and contains the main content of the individual page. This simple but effective page layout was chosen for the website due to the site needing to be an effective information portal as discussed earlier.

Text

The basis of every website is the text content that it contains and this means that the font, size, font weight, casing, layout, writing style and alignment can all affect user perception of the website, briefly these are discussed.

The Font that is to be used has to be easy to read and generally will be one of the more common font types Times New Roman, Arial, Courier, Verdana etc. When choosing font type it is also important to consider that different web browsers such as Explorer, Firefox and Opera may not accept some font types. Due to the need for maximum accessibility it was decided to use Arial text throughout the website, which is accepted by all web

browsers and software used by people with various disabilities such as blindness, that can read out the text content on websites. Font size and weight e.g. Bold or Italic are a simple and effective way of helping the user to navigate through websites and should follow a hierarchy as in standard text, with larger heavier text as titles and headings with smaller, lighter weight text to be used for most content, this should be consistent throughout the website. It is also important to make sure UPPERCASE is used sparingly as without the availability of tone as in speech the user may think that the text is 'shouting' everything, where the actual text may be purveying a more subtle message.

Finally the writing style should be concise and succinct, to keep users attention and gain future visits from them. It should be noted that reading from a computer takes 25% longer than from paper based text. As in normal writing, paragraphs should be used effectively and the text should be aligned to the left as this increases reading speed by focusing the eyes primarily on the left, which also aids users with dyslexia. This also has the fringe benefit of aiding formatting when users want to print web pages.

Colour

As stated in earlier in this chapter usability is paramount to achieve the stated research aims and as such the colours used in the website need to maximise the usability and appeal of the website to all users, to this end the website design followed basic design principles. The first issue with colour choice in web design is the ability of all users and the machine/device they use to access the website, as with resolution there is a large range of options for colour display. Bit Depth is the number of bits[2] needed to create a colour on a monitor. A bit can be used to make two colours for example black and white, the more bits used the more colours that can be created. 32 bits can make 16.7 million colours when used in various combinations, however the amount of bits that are available to the user depends on the graphic card installed within the computer, thus if a user's computer only has an 8-bit graphic card that allows a total of 256 colours to be created then it would not be able to

[2] Short for binary digit, a bit is the smallest unit of data a computer can manage. Bits are used in various combinations to represent different kinds of data; each bit has a value of 0 or 1. First used by eminent statistician John Tukey in 1949.

render a full spectrum of colours from a 32-bit image due to the lack of bits or information processing ability.

When a graphic card with a low bit rate can't process a higher bit rate colour a process called dithering occurs whereby the graphics card attempts to make the colour using two colours that it can create. It achieves this using a check pattern of the two colours. Dithering can significantly degrade images where colours are not available and this affects the overall aesthetic quality of the site, an example of dithering is shown in Figure 38.

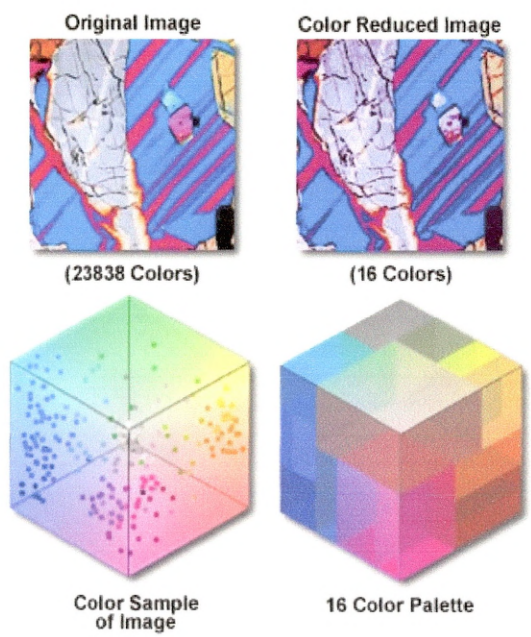

Figure 38 - Examples of Dithering

Figure 38 from Florida State University Microscopy Department, illustrates the available colours in a cube below each image. This gives an effective idea of the issues that create dithering. To overcome the problem of dithering in 1994 Netscape released the web safe palette also called the 6 X 6X 6 colour safe cube, a collection of 216 colours that could be rendered by 8-bit computers, the principal graphic card in the early 1990's. These 216 colours worked on both the Microsoft Windows and the Apple Macintosh operating platforms and have been seen as the one of the primary rules of web design.

In the last 10 years computers have become much more powerful with increasing monitor resolution and faster graphic cards, which has led to calls to stop using the web safe palette, however with the need to reach all users, it was decided for the research to use the web safe palette. It should be noted that 39% of users (n=280) to the research website were using less powerful computers and so may have been disadvantaged if the web safe palette wasn't used.

Once the technical issue of user optimisation due to bit depth is finalised colour selection and usage need to be considered carefully. There are cultural associations with colours and this can affect user satisfaction and retention, for example the colour red is associated with; Heat, Stop, Anger and warnings, Blue is associated with Water, Peacefulness and Sadness.

It is important to make sure that there is an effective contrast of colours on websites between text and the background colour choice due to the need of all users to see the content of the website. Using pale colours on white backgrounds for example creates low contrast which makes it harder for users to read the content of the website. Users with visual impairment will not be able to access the website without great difficulty, effectively removing a group of users for accessing the website. Even though yellow text on a black background is a good contrast of colours it may not be seen as aesthetically pleasing to most users. The Environment Agency uses this colour scheme on its text only website for people with visual impairment. The most common colours used for high contrast between text and background is Black text on a white background, which gives maximum accessibility to users with poor vision and helps users with dyslexia to realise the structure of words and sentences easier. This colour scheme is supported by both the Royal Institute for the Blind (RNIB) and the W3C. So black text and white background was chosen for the website.

Finally, when thinking of text colour for hyperlinks there are certain web conventions to consider. When the World Wide Web was first conceived the colour blue was used to highlight Hyperlinks, with the link changing to purple when a user had accessed it. Users now look for this convention and changing the colour of hyperlinks causes confusion and disorientates users, which in turn slows down website navigation and overall trust.

Images

An image is worth a 1000 words, and so with web design images can relay information in a quick and accessible form to most users. Images need to be high quality in the case of this research using a web safe palette. As Nielsen states many times in his book Designing Web Usability (2000), 'Users like Fast Pages', images when compared to text are much larger in file size and take longer for users to access and is based on their internet connection speed. Due to this fact images should be used sparingly and with due care to the file size.

Website Creation

The first consideration when building a website is where to 'host' the site. A Host is a server, which is a computer where the website files physically reside. There are two options available to the developer (a) host on an external private company server or (b) host on a server or computer ran within the developers' own residence or company.

Using servers ran by private companies such as freewebspace.com and fortunecity.com offers website storage usually for free in turn for adverts placed on the websites, which in turn generates revenue for the private company. The major problems with using these servers is the restrictive storage space allowed, the amount of Bandwidth (information (bits) that is allowed between websites and users computers), website design restrictions and also the Adverts that are placed on websites. Another concern is the security of information and stability of the private company's server, over which the developer has no control.

Using servers based in the own developers residence or company can generate initial costs of the server hardware purchase, registering a website domain name[3] and any costs for software packages needed to develop the website which themselves can cost up to £2000. However the advantages of a developer independently hosting a website is in direct counter to private company hosting; no size limits, as much bandwidth as the developers Internet connection supports, total design freedom, no adverts and full control on security

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[3] The address or Uniform Resource Locator (URL) of a website. The text name corresponds to a numeric Internet Protocol (IP) address of a computer on the Internet

and stability. With the research being carried out at a university and with the need to extensively design the website to meet usability and accessibility standards, the website was hosted on the university's own servers.

The next decision to make once the server was chosen is how to 'code' the website, whereby there are several types of method to create a website, briefly described .

HTML

HTML (Hyper Text Markup Language) is the programming language used to create all websites and controls all aspects of a websites structure and appearance on the World Wide Web through a system of tags[4] for individual characteristics such as background colour, text size and where hyperlinks are inserted. Writing lines of code using tags that encase the desired content such as text and images assembles Websites. This method of website creation was initially the only way of creating web content and was the primary tool of development from the internet's inception in the 1960's until the mid 1990's when software began to develop that allowed users to use visual-led design, such as FrontPage ™ and Dreamweaver ™.

Figure 39 shows a split-screen with the HTML code above translated, in this case to a simple hyperlink in the bottom of the Figure.

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[4] A Markup inserted into an HTML document to provide information about a unit of content

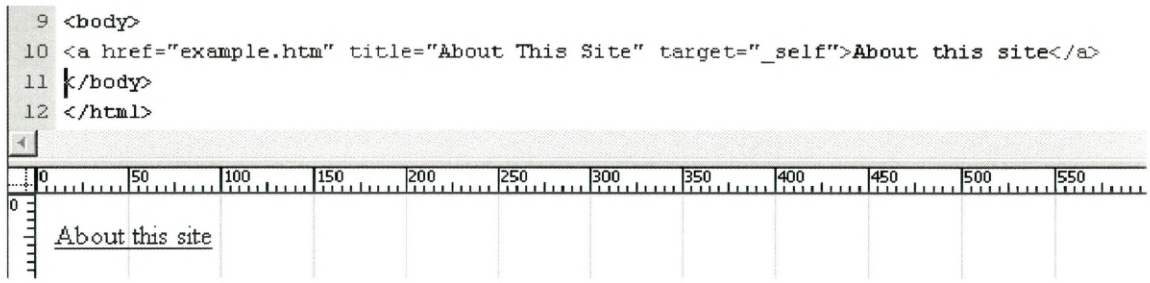

Figure 39 - Example of HTML code and the translation to the visual medium

While programming in HTML gives good control over website content, it is time-consuming and can restrict aesthetic aspirations. Design-led software or What-You-See-Is-What-You-Get Editors (WYSIWYG) can offer a number of advantages.

WYSIWYG Editors

WYSIWYG editors said "wuzzy-wig" are a Graphical User Interface (GUI)[5] in which a file being created is displayed as it will appear to an end user, using a graphical display rather than the actual code creating the file, an example of this is Dreamweaver that enables developers to create websites in much the same way as a word-processed document, without the need to learn advanced HTML code.

The software is becoming increasingly sophisticated allowing beginners to website design to create adequate websites, without the need to look at any HTML code, however there are a number of issues that need to be addressed to use them effectively. The main issue with the editors is that the HTML code that they generate is not always as well written as if it was coded directly, this can lead to excessive code being created which can disadvantage users with accessibility issues who users programs to translate websites. Related to accessibility, WYSIWYG editors also do not create ALT-tags which are text based descriptors of images, which visually impaired users need to fully understand a website, as a result to qualify for W3C 1.0 guidelines (W3C, 2000), ALT-tags need to be specifically

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[5] A user interface based on graphics (icons and pictures and menus) instead of text – (Encarta 2005)

created for every image on a website. The other issue with the editors is that more advanced functions need to be coded specifically.

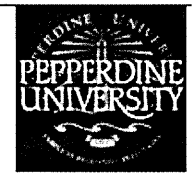
When creating this website, Dreamweaver MX 2004 WYSIWYG editor was used primarily, with HTML coding used when needed for advanced functions such as online forms and for accessibility issues. A survey of web developers in 2004 showed that using multiple tools and methods for web design was common (Rosson et al., 2005).

Of the two most widely used WYSIWYG editors Microsoft FrontPage ™ and Macromedia Dreamweaver MX™, Dreamweaver was chosen for the following reasons; FrontPage is relatively cheap (£200~) to buy and is a useful way into web design due to it using the same layout as other Microsoft Office ™ Applications, however Dreamweaver MX, which initially is harder to learn and much more expensive (£700~) utilises more advanced technologies that are needed when creating a user-driven website. It should also be noted that the researcher had used Dreamweaver extensively previous to this research.

APPENDIX 3 – US SURVEY TEMPLATE AND DATASET

This appendix contains the survey template used in the United States and discussed in Chapter five. This is shown in Figure 40 on the next page. Table 28 this shows the data from the 19 respondents to the surveys.

Bathing Water research Surveys
United States Comparison work



RESEARCH QUESTIONS

elow and mark on the scale whether you agree or disagree with the statement and to what extent

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Figure 40 - Design template of US surveys

APPENDIX 4 – BATHING WATER PROFILE

Angus is an area of 2,200km^2, situated on Scotland's northeast coast and is geologically characterised by mountains, glens, rivers, rugged cliffs and seaside towns. Agriculture, farming, forestry and fishing, comprise the base of the Angus economy. The Arbroath river catchment comprises the total land mass drained by the Elliot Water, and the Brothock Water and their tributaries, both outflow onto Arbroath West Links beach and the harbour respectively, with a distance of 2.63km between them.

The Elliot catchment covers 37.1km^2 and Brothock catchment 46.82km^2. Discharges in the Elliot catchment come from several septic tanks as well as from cattle herds and other agriculture within the catchment. Pollution from human and animal waste is a primary cause of failing water quality at several Scottish bathing waters due to high levels of nutrients and enteric pathogens. Residues of either or both of these sources of pollution can end up in the Arbroath bathing water which can lead to a lowering of water quality and reduce the recreational value of inland and bathing water. This can have inherent effects on tourism also. Figure 41 shows a map of the west links bathing water, with the pollution sources that can affect it, including the Brothock and Elliot watercourses. Table 29 gives a more detailed text-based description of these pollution sources.

Figure 41- Map of sources of pollution affecting Arbroath Bathing Water

Table 29- Key to Figure 41 map

Map Point	**Name**	**Description of Factors**	**OS Grid Reference**
1	Elliot Outfall	Linked to several septic Tanks (Only works on extremely low tides	Not available
2	Elliot Water	Agricultural Run-off and septic tanks	Contact with Beach 361900,739400
3	Gordies Burn	Agricultural Run-Off	Contact with Beach 362600,739900
4	Inchcape Long Outfall	Long Outfall – CSO	364160,739310
5	Inchcape Short Outfall	Short Outfall – CSO	364350,740150
6	Brothock Water	Agricultural Run- off and septic tanks	364400,740600

Work carried out by SEPA in 2004 highlighted that the most important source of pollution when related to the failure of the Bathing Water was the Inchcape Short Outfall. All information within the Bathing Water Profile has been sourced from SEPA, Scottish Waters and work carried out by the Urban Water Technology Centre (UWTC).

APPENDIX 5 – RAW BIOLOGICAL DATA

This appendix contains the raw data for biological monitoring for Growth, Respiration and NRR. This contains all data for all test organisms over both 28 day cycles.

Growth data – 28 day cycle 1

		Mussel						STD	WW/DW
	Day 3	1	2	3	4	5	Average	DEV	Ratio
	Wet Weight	4.35	4.11	4.35	no	no	4.27	0.138564	
	Dry Weight	0.54	0.52	0.55	no	no	0.536667	0.015275	
AB1	Length	62	61	64	no	no	62.33333	1.527525	7.956521739
	Wet Weight	5.92	5.25	4.05	5.33	6.01	5.312	0.783211	
	Dry Weight	0.75	0.66	0.53	0.67	0.75	0.672	0.090111	
AB2	Length	70	63	58	64	66	64.2	4.38178	7.904761905
	Wet Weight	4.2	4.18	4.03	5.22	6.03	4.732	0.866528	
	Dry Weight	0.51	0.52	0.48	0.57	0.68	0.552	0.078549	
AB3	Length	55	61	57	62	65	60	4	8.572463768
		Mussel						STD	WW/DW
	Day 10	1	2	3	4	5	Average	DEV	Ratio
	Wet Weight	3.02	3.21	3.98	4.29	2.81	3.462	0.639898	
	Dry Weight	0.38	0.4	0.49	0.55	0.38	0.44	0.076485	
AB1	Length	54	56	58	60	53	56.2	2.863564	7.868181818
	Wet Weight	4.2	2.7	2.64	5.33	2.55	3.484	1.236903	
AB2	Dry	0.58	0.35	0.34	0.68	0.33	0.456	0.16288	7.640350877

	Weight								
	Length	62	54	52	63	52	56.6	5.458938	
	Wet Weight	5.1	3.89	4.39	4.62	3.52	4.304	0.617843	
	Dry Weight	0.66	0.51	0.53	0.59	0.45	0.548	0.080125	
AB3	Length	64	59	60	62	57	60.4	2.701851	7.854014599
		Mussel						STD	WW/DW
	Day 13	1	2	3	4	5	Average	DEV	Ratio
	Wet Weight	4.02	4.43	3.18	3.75	4.71	4.018	0.596381	
	Dry Weight	0.48	0.53	0.38	0.47	0.61	0.494	0.084439	
AB1	Length	58	62	54	57	63	58.8	3.701351	8.133603239
	Wet Weight	3.12	5.23	4.56	3.47	4.08	4.092	0.843487	
	Dry Weight	0.52	0.66	0.58	0.44	0.51	0.542	0.082583	
AB2	Length	61	65	63	56	59	60.8	3.49285	7.549815498
	Wet Weight	3.11	3.42	3.54	3.89	2.89	3.37	0.387234	
	Dry Weight	0.37	0.41	0.46	0.48	0.37	0.418	0.050695	
AB3	Length	53	56	57	57	54	55.4	1.81659	8.062200957
		Mussel						STD	WW/DW
	Day 16	1	2	3	4	5	Average	DEV	Ratio
	Wet Weight	3.12	3.61	4.21	3.38	2.99	3.462	0.481633	
	Dry Weight	0.35	0.44	0.52	0.44	0.33	0.416	0.077006	
AB1	Length	52	56	59	57	53	55.4	2.880972	8.322115385
AB2	Wet Weight	3.23	3.98	4.72	3.88	3.33	3.828	0.597302	8.042016807

	Dry Weight	0.4	0.54	0.59	0.47	0.38	0.476	0.08961	
	Length	55	62	63	58	54	58.4	4.037326	
	Wet Weight	3.16	3.65	4.29	3.4	4.81	3.862	0.676956	
	Dry Weight	0.36	0.46	0.53	0.43	0.62	0.48	0.099247	
AB3	Length	51	57	58	56	64	57.2	4.658326	8.045833333
		Mussel						STD	WW/DW
	Day 21	1	2	3	4	5	Average	DEV	Ratio
	Wet Weight	4.52	4.21	3.42	3.12	4.31	3.916	0.609533	
	Dry Weight	0.57	0.5	0.41	0.38	0.53	0.478	0.080436	
AB1	Length	62	59	55	54	61	58.2	3.563706	8.192468619
	Wet Weight	4.41	4.45	4.32	3.12	3.06	3.872	0.71573	
	Dry Weight	0.54	0.59	0.54	0.37	0.37	0.482	0.104259	
AB2	Length	60	63	61	55	54	58.6	3.911521	8.033195021
	Wet Weight	3.61	4.38	4.11	4.08	5.42	4.32	0.674426	
	Dry Weight	0.35	0.52	0.51	0.65	0.69	0.544	0.13409	
AB3	Length	55	58	57	64	66	60	4.743416	7.941176471
		Mussel						STD	WW/DW
	Day 23	1	2	3	4	5	Average	DEV	Ratio
	Wet Weight	4.28	3.54	4.02	4.21	4.12	4.034	0.292882	
	Dry Weight	0.48	0.36	0.55	0.53	0.58	0.5	0.086313	
AB1	Length	58	55	61	59	64	59.4	3.361547	8.068
AB2	Wet	3.99	4.11	3.77	4.05	3.55	3.894	0.231257	8.078838174

	Weight								
	Dry Weight	0.46	0.45	0.6	0.55	0.35	0.482	0.096799	
	Length	57	58	63	60	54	58.4	3.361547	
	Wet Weight	4.31	4.66	4.43	4.51	3.92	4.366	0.279875	
	Dry Weight	0.49	0.71	0.66	0.56	0.34	0.552	0.146185	
AB3	Length	58	66	64	61	53	60.4	5.128353	7.90942029
		Mussel						STD	WW/DW
	Day 28	1	2	3	4	5	Average	DEV	Ratio
	Wet Weight	4.06	4.02	3.82	3.78	3.66	3.868	0.168285	
	Dry Weight	0.42	0.54	0.59	0.46	0.38	0.478	0.086139	
AB1	Length	56	61	63	58	54	58.4	3.646917	8.092050209
	Wet Weight	3.42	3.55	3.76	4.01	3.55	3.658	0.231452	
	Dry Weight	0.37	0.62	0.33	0.65	0.31	0.456	0.165167	
AB2	Length	55	64	52	63	52	57.2	5.890671	8.021929825
	Wet Weight	4	3.95	3.66	3.37	4.21	3.838	0.327063	
	Dry Weight	0.53	0.48	0.46	0.34	0.63	0.488	0.105688	
AB3	Length	60	59	58	52	63	58.4	4.037326	7.864754098

Growth Data – 28 Day Cycle 2

		Mussel						STD	WW/DW
	Day 3	1	2	3	4	5	Average	DEV	Ratio
	Wet Weight	3.52	4.48	3.87	4.64	3.12	3.926	0.639203	
	Dry Weight	0.43	0.58	0.49	0.6	0.37	0.494	0.097622	
AB1	Length	56	61	58	63	54	58.4	3.646917	7.947368421
	Wet Weight	4.03	3.03	5.21	5.21	2.78	4.052	1.15595	
	Dry Weight	0.51	0.35	0.62	0.65	0.34	0.494	0.145705	
AB2	Length	59	53	64	65	52	58.6	6.024948	8.20242915
	Wet Weight	2.23	3.44	2.78	4.36	3.97	3.356	0.864829	
	Dry Weight	0.26	0.44	0.36	0.56	0.49	0.422	0.116276	
AB3	Length	47	56	53	62	58	55.2	5.630275	7.952606635
		Mussel						STD	WW/DW
	Day 7	1	2	3	4	5	Average	DEV	Ratio
	Wet Weight	3.21	3.26	4.24	4.42	3.42	3.71	0.574804	
	Dry Weight	0.41	0.44	0.54	0.56	0.39	0.468	0.077266	
AB1	Length	55	57	62	61	54	57.8	3.563706	7.927350427
	Wet Weight	4.32	4.67	3.3	3.25	4.33	3.974	0.653705	
	Dry Weight	0.56	0.59	0.43	0.36	0.55	0.498	0.098336	
AB2	Length	62	65	56	52	61	59.2	5.167204	7.979919679
	Wet								
AB3	Weight	3.5	4.45	3.19	3.39	4.28	3.762	0.564774	8.17826087

	Dry Weight	0.36	0.57	0.37	0.46	0.54	0.46	0.095656	
	Length	52	64	53	57	60	57.2	4.969909	
		Mussel						STD	WW/DW
	Day 10	1	2	3	4	5	Average	DEV	Ratio
	Wet Weight	4.12	4.84	4.52	3.43	3.28	4.038	0.675737	
	Dry Weight	0.4	0.62	0.55	0.44	0.37	0.476	0.105499	
AB1	Length	57	65	63	58	55	59.6	4.219005	8.483193277
	Wet Weight	4.33	3.72	3.66	4.89	3.46	4.012	0.588617	
	Dry Weight	0.54	0.43	0.39	0.59	0.41	0.472	0.087864	
AB2	Length	62	59	55	63	58	59.4	3.209361	8.5
	Wet Weight	3.87	4.53	3.17	3.69	4.03	3.858	0.495702	
	Dry Weight	0.39	0.53	0.34	0.49	0.53	0.456	0.086487	
AB3	Length	57	61	54	60	62	58.8	3.271085	8.460526316
		Mussel						STD	WW/DW
	Day 13	1	2	3	4	5	Average	DEV	Ratio
	Wet Weight	3.62	4.22	3.96	4.53	4.71	4.208	0.436772	
	Dry Weight	0.41	0.52	0.47	0.56	0.58	0.508	0.069065	
AB1	Length	56	60	58	61	62	59.4	2.408319	8.283464567
	Wet Weight	4.29	3.87	4.21	5.01	5.32	4.54	0.601997	
	Dry Weight	0.43	0.44	0.5	0.61	0.71	0.538	0.119875	
AB2	Length	57	55	60	63	66	60.2	4.438468	8.43866171
AB3	Wet	4.62	3.77	3.59	3.21	4.29	3.896	0.561142	8.016460905

	Weight								
	Dry Weight	0.62	0.44	0.47	0.37	0.53	0.486	0.094499	
	Length	62	54	59	52	61	57.6	4.393177	
		Mussel						STD	WW/DW
	Day 21	1	2	3	4	5	Average	DEV	Ratio
	Wet Weight	3.46	3.53	3.71	4.61	3.31	3.724	0.515732	
	Dry Weight	0.42	0.45	0.51	0.59	0.33	0.46	0.097468	
AB1	Length	56	55	59	62	49	56.2	4.868265	8.095652174
	Wet Weight	3.61	3.21	5.21	4.51	2.58	3.824	1.044261	
	Dry Weight	0.45	0.38	0.64	0.59	0.35	0.482	0.127945	
AB2	Length	57	53	63	64	52	57.8	5.540758	7.933609959
	Wet Weight	3.79	4.68	3.52	4.91	3.7	4.12	0.629087	
	Dry Weight	0.47	0.6	0.49	0.62	0.43	0.522	0.083487	
AB3	Length	58	61	59	63	56	59.4	2.701851	7.892720307
		Mussel						STD	WW/DW
	Day 23	1	2	3	4	5	Average	DEV	Ratio
	Wet Weight	4.65	5.12	3.63	4.77	3.81	4.396	0.643957	
	Dry Weight	0.61	0.65	0.49	0.62	0.45	0.564	0.088204	
AB1	Length	61	64	59	62	57	60.6	2.701851	7.794326241
	Wet Weight	3.61	4.63	4.47	3.48	4.55	4.148	0.555266	
	Dry Weight	0.43	0.63	0.58	0.44	0.59	0.534	0.092358	
AB2	Length	56	63	60	55	61	59	3.391165	7.767790262

	Wet Weight	4.12	4.66	3.39	3.38	3.01	3.712	0.66556	
	Dry Weight	0.5	0.62	0.41	0.44	0.37	0.468	0.097314	
AB3	Length	59	63	56	56	51	57	4.41588	7.931623932
		Mussel						STD	WW/DW
	Day 28	1	2	3	4	5	Average	DEV	Ratio
	Wet Weight	3.62	4.21	4.18	3.31	3.71	3.806	0.385006	
	Dry Weight	0.44	0.51	0.52	0.4	0.48	0.47	0.05	
AB1	Length	56	59	60	55	58	57.6	2.073644	8.09787234
	Wet Weight	4.42	4.09	3.55	3.46	4.32	3.968	0.44042	
	Dry Weight	0.56	0.51	0.46	0.42	0.54	0.498	0.057619	
AB2	Length	62	60	58	57	60	59.4	1.949359	7.967871486
	Wet Weight	3.64	3.5	3.73	4.7	3.09	3.732	0.594029	
	Dry Weight	0.48	0.44	0.49	0.65	0.34	0.48	0.112027	
AB3	Length	59	57	58	64	54	58.4	3.646917	7.775

Respiration Data – 28 Day Cycle 1

	Mussel						STD
Day 3	1	2	3	4	5	Average	DEV
AB1	5.77	5.15	3.17	no	no	4.696667	1.357989
AB2	1.42	2.87	1.45	2.43	1.7	1.974	0.645624
AB3	4.89	4.19	4.18	3.8	3.27	4.066	0.594079
BLANK	8.36	8.39	8.28	8.36	8.55	8.388	0.099348
AB1	0.922833333	AB2	1.6035	AB3	1.0805		
	Mussel						STD
Day 10	1	2	3	4	5	Average	DEV
AB1	4.12	4.02	4.61	4.35	4.22	4.264	0.228758
AB2	2.97	3.86	3.52	3.21	3.61	3.434	0.348325
AB3	3.6	3.72	3.81	3.63	4	3.752	0.161152
BLANK	8.19	8.14	8.22	8.11	8.16	8.164	0.042778
AB1	0.975	AB2	1.1825	AB3	1.103		
	Mussel						STD
Day 13	1	2	3	4	5	Average	DEV
AB1	6.2	5.83	6.13	5.5	5.32	5.796	0.384096
AB2	6.45	5.87	6.4	5.4	5.68	5.96	0.456563
AB3	5.34	5.55	5.76	5.43	6.02	5.62	0.273404
BLANK	8.3	8.53	8.81	9	8.66	8.66	0.26674
AB1	0.716	AB2	0.675	AB3	0.76		
	Mussel						STD
Day 16	1	2	3	4	5	Average	DEV
AB1	4.66	4.12	4.33	4.52	4.65	4.456	0.230282
AB2	4.25	4.35	4.67	4.32	4.1	4.338	0.209213
AB3	4.02	4.16	4.22	4.35	4.07	4.164	0.12973
BLANK	8.98	9.2	8.31	8.32	8.16	8.594	0.463767
AB1	1.0345	AB2	1.064	AB3	1.1075		

	Mussel						STD
Day 21	1	2	3	4	5	Average	DEV
AB1	4.56	4.62	4.44	4.83	4.34	4.558	0.186601
AB2	4.58	4.73	4.89	4.77	4.67	4.728	0.115412
AB3	4.23	4.34	4.43	4.19	4.26	4.29	0.095656
BLANK	8.32	8.26	8.36	8.71	8.45	8.42	0.17621
AB1	0.9655	AB2	0.923	AB3	1.0325		
	Mussel						STD
Day 23	1	2	3	4	5	Average	DEV
AB1	4.34	4.18	4.64	4.21	4.03	4.28	0.229456
AB2	2.9	4.54	3.51	4.7	3.99	3.928	0.74261
AB3	3.85	3.67	3.82	4.21	4.08	3.926	0.216171
BLANK	8.12	8.53	8.12	8.37	8.33	8.294	0.175585
AB1	1.0035	AB2	1.0915	AB3	1.092		
	Mussel						STD
Day 28	1	2	3	4	5	Average	DEV
AB1	4.45	4.67	4.63	4.12	4.22	4.418	0.24366
AB2	3.55	3.81	3.77	4.29	4.08	3.9	0.288097
AB3	3.89	3.72	3.96	4.23	4.44	4.048	0.285955
BLANK	8.34	8.31	8.12	8.45	8.44	8.332	0.133304
AB1	0.9785	AB2	1.108	AB3	1.071		

Respiration Data – 28 Day Cycle 2

	Mussel						STD
Day 3	1	2	3	4	5	Average	DEV
AB1	3.09	4.78	4.82	5.36	5.52	4.714	0.964355
AB2	4.42	4.67	4.56	4.64	4.52	4.562	0.099599
AB3	4.34	4.38	4.77	4.82	4.69	4.6	0.224388
BLANK	7.7	7.58	7.56	7.61	7.29	7.548	0.153851
AB1	0.7085	AB2	0.7465	AB3	0.737		
	Mussel						STD
Day 7	1	2	3	4	5	Average	DEV
AB1	4.84	5.91	5	4.21	5.4	5.072	0.634799
AB2	5.02	5.32	4.23	4.33	5.21	4.822	0.507514
AB3	4.65	4.76	4.43	4.62	4.71	4.634	0.126214
BLANK	8.41	8.26	8.28	8.28	8.3	8.306	0.059833
AB1	0.8085	AB2	0.871	AB3	0.918		
	Mussel						STD
Day 10	1	2	3	4	5	Average	DEV
AB1	2.68	4.49	1.87	2.7	2.02	2.752	1.041907
AB2	1.72	3.05	2.33	4.51	3.46	3.014	1.070107
AB3	2.72	3.12	3.08	3.67	3.82	3.282	0.453564
BLANK	7.93	7.75	7.69	7.98	7.76	7.822	0.125579
AB1	1.2675	AB2	1.202	AB3	1.135		
	Mussel						STD
Day 13	1	2	3	4	5	Average	DEV
AB1	2.84	3.49	3.57	3.27	2.87	3.208	0.340617
AB2	2.82	2.69	2.89	3.5	1.81	2.742	0.607017
AB3	2.76	3.17	2.93	2.85	3.02	2.946	0.157892
BLANK	7.52	7.56	7.89	8.41	8.12	7.9	0.377028
AB1	1.173	AB2	1.2895	AB3	1.2385		

	Mussel						STD
Day 21	1	2	3	4	5	Average	DEV
AB1	5.15	4.74	5.46	4.15	3.7	4.64	0.718714
AB2	4.62	4.73	4.23	4.78	4.55	4.582	0.216495
AB3	4.32	5.02	4.62	4.87	4.57	4.68	0.272489
BLANK	8.46	8.57	8.59	8.57	8.61	8.56	0.05831
AB1	0.98	AB2	0.9945	AB3	0.97		
	Mussel						STD
Day 23	1	2	3	4	5	Average	DEV
AB1	5.33	5.75	5.98	5.32	5.88	5.652	0.309467
AB2	4.97	5.07	5.29	5.32	5.26	5.182	0.153525
AB3	4.92	5.31	5.12	5.61	5.34	5.26	0.258167
BLANK	7.84	7.96	7.79	7.81	7.91	7.862	0.071204
AB1	1.1	AB2	1.34	AB3	1.301		
	Mussel						STD
Day 28	1	2	3	4	5	Average	DEV
AB1	4.14	6.01	3.94	4.7	3.04	4.366	1.096029
AB2	3.61	4.08	3.86	4.47	2.68	3.74	0.671454
AB3	3.58	4.22	3.95	4.06	3.72	3.906	0.257449
BLANK	7.42	7.51	7.73	7.71	7.57	7.588	0.131985
AB1	1.074	AB2	1.28	AB3	1.22		

NRR Data – 28 Day Cycle 1

DAY 3					
Arbroath 1 - Victoria Beach					
Mussel no					
Time	1	2	3	4	5
0	0	1	3	[redacted]	
15	2	1	3		
30	3	4	4		
60	4	4	4		
90	5	7	6		
120					
Arbroath 2 - Harbour					
Mussel no					
Time	1	2	3	4	5
0	3	2	0	0	0
15	3	3	3	2	0
30	4	4	5	2	3
60	5	4		3	3
90		6		5	6
120					
Arbroath 3 - Bathing Water					
Mussel no					
Time	1	2	3	4	5
0	1	5	0	1	3
15	3		0	2	3
30	3		3	2	4
60	4		5	5	5
90	8				
120					

Average Retention Time					
AB1	90	AB2	72	AB3	54
DAY 10					
Arbroath 1 - Victoria Beach					
Mussel no					
Time	1	2	3	4	5
0	0	0	0	1	0
15	0	2	1	2	3
30	0	2	1	2	4
60	3	1	2	6	4
90	4	2	5		5
120	6				
Arbroath 2 - Harbour					
Mussel no					
Time	1	2	3	4	5
0	0	0	0	0	2
15	0	0	3	0	3
30	0	1	4	3	4
60	2	2	5	6	5
90	7	6			
120					
Arbroath 3 - Bathing Water					
Mussel no					
Time	1	2	3	4	5
0	0	0	0	1	3
15	4	0	3	1	3
30	6	2	4	3	4

60		3	5	4	5
90		5			
120					
Average Retention Time					
AB1	90	AB2	72	AB3	60
DAY 13					
Arbroath 1 - Victoria Beach					
Mussel no					
Time	1	2	3	4	5
0	0	0	2	1	1
15	2	0	3	1	1
30	2	3	4	3	1
60	4	4	7	4	4
90	8	10		7	6
120					
Arbroath 2 - Harbour					
Mussel no					
Time	1	2	3	4	5
0	0	0	0	2	1
15	0	0	0	2	1
30	0	0	3	3	1
60	3	3	5	6	2
90	5	7			5
120					
Arbroath 3 - Bathing Water					
Mussel no					
Time	1	2	3	4	5

0	0	1	3	2	4
15	1	2	4	4	4
30	4	2	4	6	9
60	6	5	8		
90					
120					
Average Retention Time					
AB1	84	AB2	78	AB3	48
DAY 16					
Arbroath 1 - Victoria Beach					
Mussel no					
Time	1	2	3	4	5
0	0	1	3	1	2
15	0	3	3	1	2
30	2	3	4	4	2
60	2	4	8	7	3
90	6	5			6
120					
Arbroath 2 - Harbour					
Mussel no					
Time	1	2	3	4	5
0	3	0	2	2	1
15	3	1	2	3	1
30	4	3	3	3	3
60	9	7	7	5	4
90					8
120					
Arbroath 3 - Bathing Water					

Mussel no					
Time	1	2	3	4	5
0	0	0	1	2	2
15	0	2	1	2	2
30	3	2	4	3	2
60	5	6	5	5	8
90					
120					
Average Retention Time					
AB1	78	AB2	66	AB3	60
DAY 21					
Arbroath 1 - Victoria Beach					
Mussel no					
Time	1	2	3	4	5
0	2	3	0	0	0
15	2	3	0	2	3
30	2	3	1	3	4
60	4	4	5	4	4
90	9	9		8	8
120					
Arbroath 2 - Harbour					
Mussel no					
Time	1	2	3	4	5
0	1	0	0	0	3
15	1	0	2	0	4
30	3	0	4	2	8
60	5	5	4	3	

90			7	6	
120					
Arbroath 3 - Bathing Water					
Mussel no					
Time	1	2	3	4	5
0	0	0	1	0	2
15	0	0	3	0	4
30	1	2	3	3	5
60	6	6	5	8	
90					
120					
Average Retention Time					
AB1	84	AB2	66	AB3	54
DAY 23					
Arbroath 1 - Victoria Beach					
Mussel no					
Time	1	2	3	4	5
0	1	0	2	0	2
15	1	0	2	1	4
30	2	0	2	1	4
60	4	3	2	4	9
90	7	5	5	6	
120					
Arbroath 2 - Harbour					
Mussel no					
Time	1	2	3	4	5

0	0	0	2	0	2
15	0	0	2	2	3
30	2	3	3	4	4
60	4	6	7	7	6
90	5				
120					
Arbroath 3 - Bathing Water					
Mussel no					
Time	1	2	3	4	5
0	4	3	2	1	0
15	4	3	2	1	0
30	4	4	3	4	4
60	6	8	5	7	6
90					
120					
Average Retention Time					
AB1	84	AB2	66	AB3	60
DAY 28					
Arbroath 1 - Victoria Beach					
Mussel no					
Time	1	2	3	4	5
0	0	0	0	0	0
15	0	2	0	0	1
30	0	2	3	1	3
60	3	3	4	1	3
90	5	7	8	6	5
120					
Arbroath 2 - Harbour					
Mussel	1	2	3	4	5

no Time					
0	0	0	0	3	0
15	0	0	3	3	2
30	0	1	3	4	2
60	4	3	5	9	5
90	7	7			
120					
Arbroath 3 - Bathing Water					
Mussel no					
Time	1	2	3	4	5
0	0	1	2	0	1
15	1	1	2	0	4
30	2	4	4	3	7
60	5	7	6	5	
90					
120					
Average Retention Time					
AB1	90	AB2	72	AB3	54

NRR Data – 28 Day Cycle 2

DAY 3					
Arbroath 1 - Victoria Beach					
Mussel no					
Time	1	2	3	4	5
0	0	0	0	0	0
15	0	0	0	0	1
30	1	3	0	2	1
60	3	5	0	4	1
90	5		2	6	6
120			5		
Arbroath 2 - Harbour					
Mussel no					
Time	1	2	3	4	5
0	0	1	0	0	0
15	0	1	0	0	0
30	1	1	0	3	2
60	2	4	4	5	8
90	7	5	5		
120					
Arbroath 3 - Bathing Water					
Mussel no					
Time	1	2	3	4	5
0	1	1	0	2	0
15	2	1	0	2	0
30	2	3	1	2	2
60	5	9	7	5	5
90					
120					

Average Retention Time					
AB1	90	AB2	78	AB3	60
DAY 7					
Arbroath 1 - Victoria Beach					
Mussel no					
Time	1	2	3	4	5
0	2	1	2	1	1
15	3	1	2	1	1
30	3	1	2	1	1
60	4	5	3	2	3
90	5		6	5	7
120					
Arbroath 2 - Harbour					
Mussel no					
Time	1	2	3	4	5
0	0	0	2	0	0
15	0	1	2	0	0
30	0	1	2	1	1
60	0	6	5	2	1
90	1			5	5
120	5				
Arbroath 3 - Bathing Water					
Mussel no					
Time	1	2	3	4	5
0	0	3	0	0	0
15	0	3	1	0	1
30	2	8	2	5	2

60	5		5		4
90					6
120					
Average Retention Time					
AB1	84	AB2	84	AB3	54
DAY 10					
Arbroath 1 - Victoria Beach					
Mussel no					
Time	1	2	3	4	5
0	0	0	0	0	0
15	0	0	0	2	1
30	1	1	0	3	4
60	3	4	5	6	6
90	6	7			
120					
Arbroath 2 - Harbour					
Mussel no					
Time	1	2	3	4	5
0	0	0	0	0	0
15	1	1	3	2	1
30	2	3	4	2	1
60	6	5	5	3	4
90				8	9
120					
Arbroath 3 - Bathing Water					
Mussel no					
Time	1	2	3	4	5

0	1	2	0	3	1
15	1	3	0	5	2
30	1	3	2		5
60	2	7	6		
90	5				
120					
Average Retention Time					
AB1	72	AB2	72	AB3	51
DAY 13					
Arbroath 1 - Victoria Beach					
Mussel no					
Time	1	2	3	4	5
0	0	1	1	1	0
15	1	3	4	2	0
30	2	3	4	3	3
60	4	7	5	6	3
90	5				8
120					
Arbroath 2 - Harbour					
Mussel no					
Time	1	2	3	4	5
0	0	0	2	0	1
15	0	4	2	0	3
30	2	4	3	3	4
60	5	7	6	4	7
90				9	
120					
Arbroath 3 - Bathing Water					

Mussel no					
Time	1	2	3	4	5
0	0	0	0	0	0
15	1	2	3	3	2
30	1	5	4	4	2
60	3		6	5	7
90	6				
120					
Average Retention Time					
AB1	72	AB2	66	AB3	50
DAY 21					
Arbroath 1 - Victoria Beach					
Mussel no					
Time	1	2	3	4	5
0	0	0	0	0	0
15	2	1	3	2	2
30	2	1	3	3	4
60	2	2	8	4	4
90	7	5		9	6
120					
Arbroath 2 - Harbour					
Mussel no					
Time	1	2	3	4	5
0	0	0	0	0	0
15	1	2	3	2	4
30	2	4	3	2	4
60	5	7	4	4	8

90			7	5	
120					
Arbroath 3 - Bathing Water					
Mussel no					
Time	1	2	3	4	5
0	1	1	3	1	3
15	1	2	3	1	4
30	1	2	4	3	4
60	5	5	6	5	4
90					8
120					
Average Retention Time					
AB1	84	AB2	72	AB3	72
DAY 23					
Arbroath 1 - Victoria Beach					
Mussel no					
Time	1	2	3	4	5
0	2	0	2	1	0
15	3	2	3	1	0
30	4	4	3	2	2
60	4	5	3	4	3
90	6		7	7	5
120					
Arbroath 2 - Harbour					
Mussel no					
Time	1	2	3	4	5
0	1	2	1	0	0
15	1	2	1	0	2

30	3	3	3	3	2
60	5	5	6	7	4
90					8
120					
Arbroath 3 - Bathing Water					
Mussel no					
Time	1	2	3	4	5
0	2	1	0	0	0
15	2	3	0	4	2
30	5	4	3	4	2
60		6	6	9	5
90					
120					
Average Retention Time					
AB1	84	AB2	66	AB3	54
DAY 28					
Arbroath 1 - Victoria Beach					
Mussel no					
Time	1	2	3	4	5
0	0	0	0	0	0
15	1	2	0	1	2
30	1	2	0	3	3
60	3	4	3	8	6
90	5	7	5		
120					
Arbroath 2 - Harbour					
Mussel no					
Time	1	2	3	4	5

0	0	0	0	0	0
15	2	3	2	1	1
30	2	3	4	1	4
60	7	3	9	4	6
90		5		6	
120					
Arbroath 3 - Bathing Water					
Mussel no					
Time	1	2	3	4	5
0	0	1	1	0	0
15	0	2	1	2	3
30	2	2	3	3	3
60	5	6	7	7	5
90					
120					
Average Retention Time					
AB1	78	AB2	72	AB3	60

APPENDIX 6 – COMMUNICATIONS RAW DATASET

This appendix contains the raw dataset for all website usage data. The Table (30) shows by date the total number of unique visitors and if they were new or returning to the site. Website statistics were monitored as part of the overall framework evaluation from the 12th July 2005 until the 6th October 2005. This is a period of 87 days in total.

Table 30 - Portal users during the live testing time frame

Date	Unique Visitors	First Time Visitors	Returning Visitors
12th July 2005	5	3	0
13th July 2005	1	0	1
14th July 2005	2	0	2
15th July 2005	1	0	1
16th July 2005	0	0	0
17th July 2005	0	0	0
18th July 2005	7	2	2
19th July 2005	5	3	2
20th July 2005	5	1	4
21st July 2005	15	12	3
22nd July 2005	12	9	3
23rd July 2005	3	3	0
24th July 2005	9	6	0
25th July 2005	16	13	3
26th July 2005	5	1	4
27th July 2005	9	6	2
28th July 2005	2	2	0
29th July 2005	7	2	1
30th July 2005	0	0	0
31st July 2005	3	3	0
1st August 2005	1	1	0
2nd August 2005	2	1	1

Date	Unique Visitors	First Time Visitors	Returning Visitors
3rd August 2005	2	2	0
4th August 2005	4	0	4
5th August 2005	4	1	3
6th August 2005	6	6	0
7th August 2005	0	0	0
8th August 2005	9	3	6
9th August 2005	3	2	1
10th August 2005	2	2	0
11th August 2005	2	1	1
12th August 2005	6	3	3
13th August 2005	1	1	0
14th August 2005	0	0	0
15th August 2005	1	1	0
16th August 2005	0	0	0
17th August 2005	0	0	0
18th August 2005	4	1	3
19th August 2005	2	0	2
20th August 2005	0	0	0
21st August 2005	0	0	0
22nd August 2005	1	0	1
23rd August 2005	2	1	1
24th August 2005	2	0	2
25th August 2005	5	5	0
26th August 2005	5	0	5
27th August 2005	0	0	0
28th August 2005	0	0	0
29th August 2005	3	1	2
30th August 2005	3	2	1
31st August 2005	2	1	1
1st September 2005	0	0	0
2nd September 2005	1	0	1

Date	Unique Visitors	First Time Visitors	Returning Visitors
3rd September 2005	1	1	0
4th September 2005	0	0	0
5th September 2005	1	0	1
6th September 2005	2	1	1
7th September 2005	0	0	0
8th September 2005	1	0	1
9th September 2005	1	0	1
10th September 2005	0	0	0
11th September 2005	0	0	0
12th September 2005	3	2	1
13th September 2005	0	0	0
14th September 2005	0	0	0
15th September 2005	1	0	1
16th September 2005	1	0	1
17th September 2005	0	0	0
18th September 2005	0	0	0
19th September 2005	3	2	1
20th September 2005	29	27	2
21st September 2005	1	0	1
22nd September 2005	0	0	0
23rd September 2005	4	2	2
24th September 2005	0	0	0
25th September 2005	0	0	0
26th September 2005	2	0	2
27th September 2005	0	0	0
28th September 2005	17	15	2
29th September 2005	3	1	2
30th September 2005	0	0	0
1st October 2005	0	0	0
2nd October 2005	0	0	0
3rd October 2005	3	1	2

4th October 2005	1	0	1
5th October 2005	3	3	0
6th October 2005	0	0	0
Total Numbers	Unique Visitors	First Time Visitors	Returning Visitors
	255	156	88

APPENDIX 7 – SEPA MICROBIOLOGY RESULTS

In this appendix the bathing water microbiology results recorded by SEPA are outlined.

Arbroath (West Links) Results				
Date	Total Coliforms (colonies/100ml)	Faecal Coliforms (colonies/100ml)	Faecal Streptococci (colonies/100ml)	Abnormal Weather Waiver
8-Jun-2005	6 (G)	4 (G)	<2 (G)	-
	☺ : Excellent Quality			
13-Jun-2005	16 (G)	16 (G)	<2 (G)	-
	☺ : Excellent Quality			
16-Jun-2005	20 (G)	20 (G)	3 (G)	-
	☺ : Excellent Quality			
21-Jun-2005	34 (G)	34 (G)	6 (G)	-
	☺ : Excellent Quality			
29-Jun-2005	36 (G)	36 (G)	22 (G)	-
	☺ : Excellent Quality			
7-Jul-2005	14 (G)	6 (G)	2 (G)	-
	☺ : Excellent Quality			
11-Jul-2005	2 (G)	2 (G)	<2 (G)	-
	☺ : Excellent Quality			
14-Jul-2005	24 (G)	24 (G)	2 (G)	-
	☺ : Excellent Quality			
19-Jul-2005	72 (G)	52 (G)	14 (G)	-
	☺ : Excellent Quality			
23-Jul-2005	210 (G)	90 (G)	4 (G)	-
	☺ : Excellent Quality			
27-Jul-2005	28 (G)	22 (G)	13 (G)	-
	☺ : Excellent Quality			
1-Aug-2005	12 (G)	8 (G)	2 (G)	-
	☺ : Excellent Quality			
3-Aug-2005	62 (G)	42 (G)	64 (G)	-
	☺ : Excellent Quality			
10-Aug-2005	82 (G)	26 (G)	13 (G)	-
	☺ : Excellent Quality			
12-Aug-2005	6 (G)	2 (G)	2 (G)	-
	☺ : Excellent Quality			
17-Aug-2005	36 (G)	6 (G)	22 (G)	-
	☺ : Excellent Quality			
24-Aug-2005	162 (G)	38 (G)	52 (G)	-
	☺ : Excellent Quality			
30-Aug-2005	18 (G)	18 (G)	130	-
	☺ : Good Quality			
8-Sep-2005	20 (G)	20 (G)	6 (G)	-
	☺ : Excellent Quality			

APPENDIX 8 – BACKGROUND ENVIRONMENTAL MEASUREMENTS

This appendix contains the background environmental measurements recorded in support of biomonitoring in chapter three. Every time organisms were collected for testing Air Temperature (Celsius), Water Temperature (Celsius) and Water Salinity (parts per thousand) were measured. Also meteorological conditions and any other observations were noted. This information was collected so that if and when organisms were stressed or degraded other factors could be assessed.

Sample Day	Air Temp (C°)	Water Temp (C°)	Water Salinity (ppt)	Meteorological Conditions	Other observations
1st Cycle					
1	15.4	14.2	38.4	Fine	
3	17.8	14.4	38.5	Fine	
10	17.0	14.6	37.2	Light Showers	
13	11.0	14.5	37.5	Stormy/Rain	
16	15.0	14.1	37.5	Light Showers	
21	13.0	15.2	38	Sunny	
23	17.9	15.1	37	Light Showers	
28	14.18	15.1	37.8	Sunny intervals	
2nd Cycle					
1	13.0	15.2	38.3	Intermittent Showers	
3	17	15.7	37.6	Light Showers	
7	9.5	15.7	38.2	Sunny Intervals	
10	12.5	13.1	38.6	Sunny Intervals	Signs of recent storm, e.g. seaweed deposition
13	18.0	14.1	37.5	Sunny Intervals	Strong sewage smell. Sewage Related Deposits on beach
21	11.5	14.5	36.9	Sunny Intervals	
23	11.5	14.1	37.6	Sunny Intervals	
28	13	11.3	38.3	Sunny	